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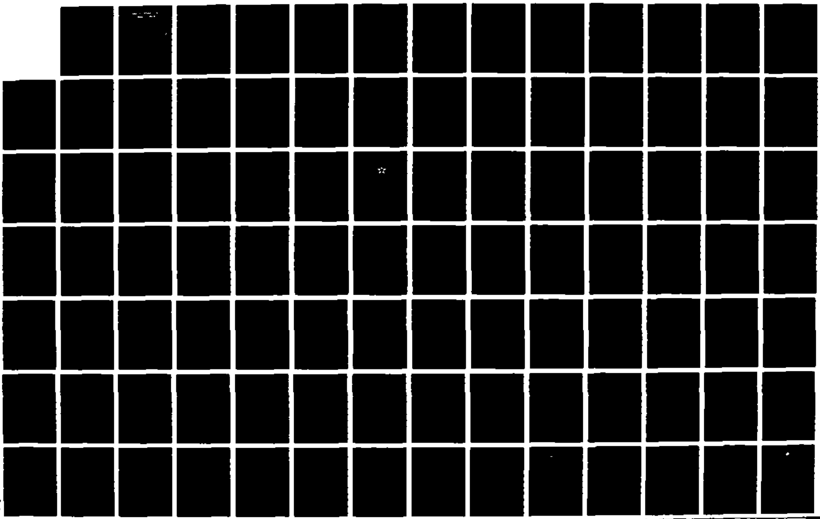

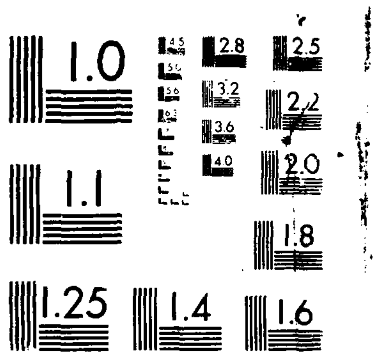

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THESIS

THE NEAR REAL TIME INFORMATION SYSTEM

by

Mark R. Wise
and
Francis G. Mahon

March 1988

Thesis Advisor MAJ Thomas J. Brown, USAF

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This thesis is a study in which the authors define and develop a U.S. Army requirement for automatic generation and distribution of near real time battlefield information for command and control. This information consists of identification, position, combat posture, and operational readiness, and allows commanders and staffs to more effectively and efficiently command and control U.S. forces on the AirLand battlefield. The proposed system interfaces with and complements the Army Tactical Command and Control System. Methodologies are developed and applied to determine operational and organizational requirements. A technical solution to the stated requirement is proposed and developed. The technical concept integrates mature, off the shelf, very low frequency, radar beacon and computer technologies in a realistic, technically feasible approach to generate the desired battlefield information. A methodology to assess operational merit is developed and applied to the concept. The proposed solution is shown to be a low cost, low risk, high payoff system which meets the stated requirement. The product of this work is an Operational and Organizational Plan.

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The Near Real Time Information System

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Submitted in partial fulfillment of the
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from the

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ABSTRACT

This thesis is a study in which the authors define and develop a U.S. Army requirement for automatic generation and distribution of near real time battlefield information for command and control. This information consists of identification, position, combat posture, and operational readiness, and allows commanders and staffs to more effectively and efficiently command and control U.S. forces on the AirLand battlefield. The proposed system interfaces with and complements the Army Tactical Command and Control System. Methodologies are developed and applied to determine operational and organizational requirements. A technical solution to the stated requirement is proposed and developed. The technical concept integrates mature, off the shelf, very low frequency, radar beacon and computer technologies in a realistic, technically feasible approach to generate the desired battlefield information. A methodology to assess operational merit is developed and applied to the concept. The proposed solution is shown to be a low cost, low risk, high payoff system which meets the stated requirement. The product of this work is an Operational and Organizational Plan.

THESIS DISCLAIMER

The beliefs and concept set forth in this thesis are the result of extensive research, professional and technical discussions, and the author's military experiences. Where appropriate, the authors have cited references and given credit to others for their ideas and concepts. Any parallels or likeness between the concept espoused in this thesis and other concepts or proposed command and control systems is unintentional and purely coincidental.

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ACKNOWLEDGEMENT

We wish to gratefully acknowledge the guidance, encouragement, and technical advice of MAJ Thomas J. Brown, Mr. Joseph T. Saganowich, and Mr. George B. Litchford, without whose support, this thesis would not have been possible. Their support and knowledge of the subject matter enabled us to develop a more complete and accurate document and greatly enhanced our knowledge and understanding of the technologies embodied in the concept. We are greatly indebted to them and wish to express our sincere thanks and appreciation.

I. THE COMMANDER'S NEEDS

A. COMMAND AND CONTROL OF AIRLAND BATTLE

1. Command and Control

Command and control is defined as, "...the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission." [Ref. 1:p. 77]. Command and control is an intangible, it is not a commodity that a commander can requisition or touch, yet it is something that every commander knows he must possess or exercise if he is to succeed. A commander's force may be very large and possess tremendous firepower or combat potential but these attributes are worthless if a commander cannot effectively employ that force, transform its combat potential into combat power, and bring it to bear on the enemy at the critical time and place. Command and control is the essential ingredient that will enable a commander to perform that transformation. It is the synergistic catalyst which enables a commander of a smaller force to defeat a larger force.

2. A Command and Control System

To effectively exercise command and control (C2) over their assigned forces, commanders have developed command and control systems. A command and control system is defined as, "...the facilities, equipment, communications, procedures and personnel essential to a commander for planning, directing, and controlling operations of assigned forces pursuant to the missions assigned." [Ref. 1:p. 77].

A command and control system is a tool which a commander will use to plan, direct, and control his forces. To effectively use this tool a commander must have a process or organized manner of directing the tool's energy so as to realize the most benefit from its employment. A commander must have a command and control process which will enable him to efficiently employ his command and control system and provide effective command and control to his force thereby accomplishing the assigned mission.

3. The Command and Control Process

J.S. Lawson Jr. has developed a model of the command and control process. In his model, Lawson defined the process as one consisting of an environment, five primary functions, and extraneous factors. These elements are unique and can be described as follows:

1. The environment consists of the commander's forces, his enemy's forces, and the combat environment (the mission, the time he has available to execute the nission and the natural environment in which the forces will interact).
2. The five primary functions the C2 system must perform are: sense, process, compare, decide, and act.
3. The extraneous factors which the system must consider are: external data, the desire to reach a specified state, and decision aids

The first step of the process is to 'sense' the environment has changed. This sensing is the result of data being received about the environment. This data is processed and integrated with external information to produce an estimate of the situation. This estimate is compared to a desired state that the commander wishes the environment would represent. The commander then decides if the environment and the desired state are similar. If they are not, he must take some action to alter the environment and to cause it to conform to the desired state. Figure 1 is an illustration of the Lawson Command and Control Process Model. [Ref. 2:p. 24]

As previously discussed, the command and control process is applied by a commander's C2 system to the environment. A measure of effectiveness for a C2 system and its application of the C2 process, is a function of Lawson's environment. To put it more succinctly, "...it is a function of friendly forces, enemy forces, and the combat environment." [Ref. 3]. The sections which follow will discuss the effect those three environmental elements have on a modern C2 system's design.

B. C2 SYSTEM DESIGN CONSIDERATIONS

1. Friendly Forces

a. AirLand Battle Doctrine

To successfully conduct military operations the U.S. Army has developed a doctrine known as AirLand Battle. This doctrine has been defined as follows: "...the U.S. Army's basic fighting doctrine....it reflects the structure of modern warfare, the dynamics of combat power, and the application of the classical principles of war to contemporary battlefield requirements." [Ref. 4:p. 9].

This definition identifies three key elements that are integrated into the AirLand Battle doctrine. Each of these key elements represents a unique aspect of war which impacts on the development and execution of doctrine. The elements and their meaning under the AirLand Battle (ALB) doctrine are as follows:

- The Structure of Modern Warfare: describes the modern battlefield on which AirLand Battle doctrine will be executed, the AirLand battlefield.

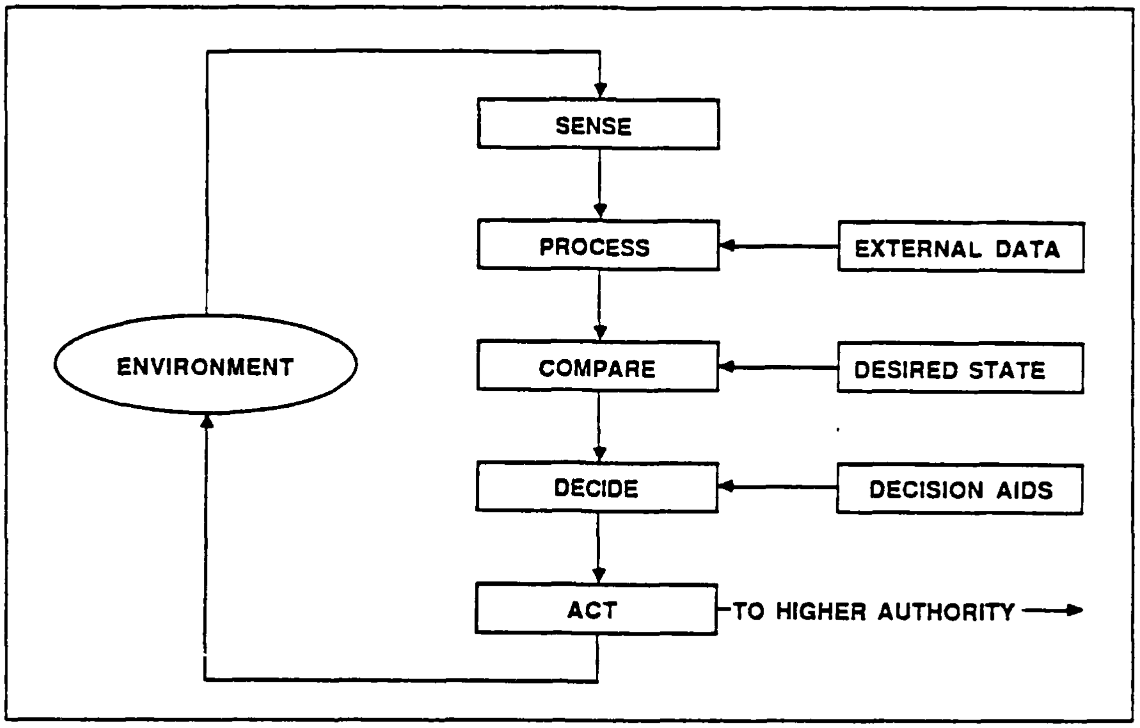

Figure 1. Lawson's Command and Control Process

- The Dynamics of Combat Power: deals with the generation of combat power and a commander's application of it to the AirLand battlefield.
- The Principles of War on the Contemporary Battlefield: describes the incorporation of the nine basic principles of war into the AirLand Battle Tenets and Imperatives. Through the tenets and imperatives the commander will apply combat power to the modern battlefield and achieve his objective.

b. The AirLand Battlefield

The AirLand battlefield will be an area of dynamic action. Combat operations on this battlefield will be executed at greater speeds, with greater lethality, and destruction than ever before. This battlefield will be a complex, multidimensional battle area that will integrate both air and land combat operations in combined arms operations. The concept of integrated combat operations requires the Army to be prepared to plan and conduct combat operations on a three dimensional battlefield. Future battles will be fought across the full width of the battlefield, at great depths along the battlefield, and in the third dimension, the airspace above the battlefield.

The three dimensional battle area requires a command and control system that can simultaneously plan, control, and direct combat operations in all three dimen-

sions. Figure 2 illustrates the multidimensional characteristics of the AirLand battlefield.

The concept of fighting in three dimensions is compounded by the fact that AirLand Battle doctrine also requires a commander to simultaneously conduct three different operations while he fights, plans, and controls combat operations (battles) in three dimensions. These battles are closely related to the three dimensions of AirLand battlefield and are known as:

- deep operations,
- rear operations,
- close operations.

Deep operations are described as activities directed against enemy forces that are not yet in contact with friendly forces along the front line of troops (FLOT). Deep operations are designed to influence the conditions in which future close operations will be conducted. A principal objective of deep operations is to deny the enemy commander the freedom of action. With deep operations, a commander will disrupt the enemy's continuity of action and the tempo of his operations thereby causing him to become responsive to the friendly commander's actions. [Ref. 4:p. 19]

Rear operations are described as activities conducted to the rear of elements in contact. These operations are designed to ensure freedom of maneuver and continuity of operations, including continuity of sustainment and maintenance of command and control. Rear operations have little immediate impact on close operations, but are critical to subsequent operations, whether in exploiting success or recouping failure. Rear operations are essential to ensure friendly forces defeat the enemy's operations in our rear areas with minimum expenditure of resources. [Ref. 4:p. 20]

Close operations are described as the current activities of major committed combat elements, together with their immediate combat support and combat service support. Close operations are those activities currently transpiring at the FLOT, at this moment. Close operations bear the ultimate burden of victory or defeat. The measure of success of deep and rear operations is their eventual impact on close operations. [Ref. 4:p. 19]

As the last statement infers, none of these operations are conducted in isolation and they each impact on the others. In view of this, they are graphically depicted as three circles, with the center circle, close operations, being the focal point. Figure 3 provides an illustration of this concept.

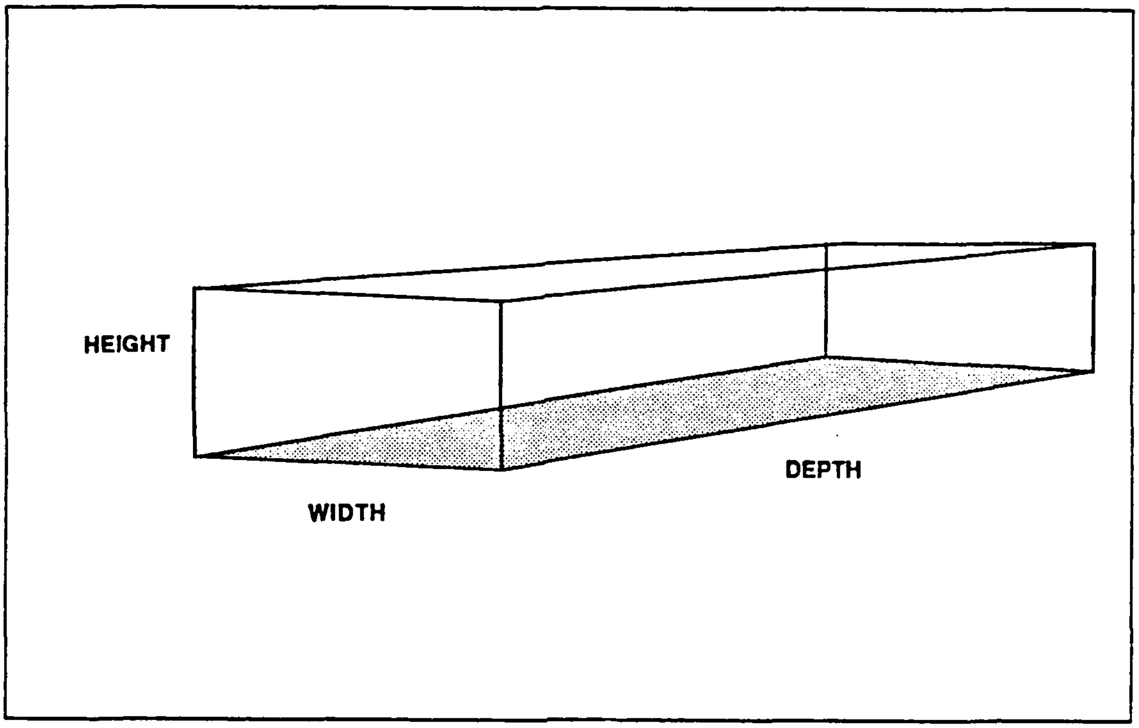

Figure 2. The Dimensions of the AirLand Battlefield

Under AirLand Battle doctrine, commanders, at various levels of command, must be concerned with conducting these three simultaneous operations. In addition, commanders must conduct these operations on a three dimensional battlefield that may be influenced by the use of: nuclear and chemical weapons, electronic warfare (EW), conventional weapons with greatly enhanced accuracy and lethality, high technology sensors, and smart munitions.

A commander conducting operations on this battlefield may also have to operate with joint or combined forces. The air assets operating above the commander may belong to the U.S. Navy; the ground forces operating to the commander's left may be from the U.S. Marine Corps; and the forces conducting operations on the commander's right flank might be a NATO (North Atlantic Treaty Organization) ally. Each of these participants adds its own set of doctrine, organizations, and equipment to the complexity of the AirLand battlefield.

The AirLand Battle doctrine will be applied to a complex, multidimensional battlefield. A commander operating on this battlefield requires a command and control system that is capable of:

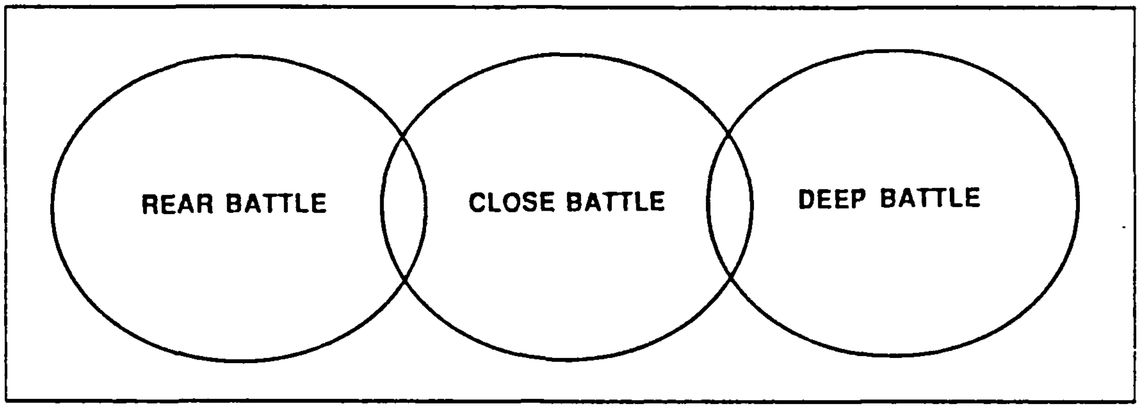

Figure 3. The Three Operations of AirLand Battle

- presenting the battlefield as a three dimensional battle area;
- displaying the battle in sufficient width and depth to depict the commander's three simultaneous operations;
- interfacing with the command and control systems of other forces in joint and combined operations;
- operating efficiently in spite of the enemy's electronic countermeasures;
- providing continuous operations in spite of nuclear, biological, or chemical (NBC) warfare.

2. The Dynamics of Combat Power

The dynamics of combat power will decide the outcomes of campaigns, major operations, battles and engagements. Combat power is the ability to fight; the ability to alter the situation on the battlefield or change the environment. Combat power is composed of the following four elements:

- maneuver,
- firepower,
- protection,
- leadership. [Ref. 4:p. 11]

Maneuver is the dynamic element of combat. It is the means of concentrating forces at the critical point to achieve surprise and shock, to attain momentum and moral dominance which enables smaller forces to defeat larger forces. [Ref. 4:p. 11]

Firepower is the essential destructive force that defeats the enemy's physical and mental commitment to fight. It facilitates a force's ability to maneuver. Long range

firepower confounds the enemy's ability to mass his forces at the critical time and place. [Ref.4:p. 12]

Protection is the conservation of fighting potential until the critical point is reached. It includes all actions taken to lessen the effects of the enemy's efforts to employ maneuver or firepower against friendly forces. [Ref. 4: p. 13]

Leadership provides the purpose, direction and motivation to the force. It is the leader who will determine the degree to which maneuver, firepower, and protection are maximized; who will ensure these elements are effectively balanced; and who will decide how to bring them to bear against the enemy. It is the leader who must employ the C2 system to its fullest to transform his force's combat potential into combat power. Leadership is considered to be the most essential element of combat power. [Ref. 4:p. 13]

A command and control system that supports a commander under AirLand Battle doctrine must enhance the dynamics of combat power. The system must assist, not hinder, the commander as he endeavors to maximize maneuver and the firepower of his force so as to bring them to bear on the enemy at the critical point. The command and control system must permit free maneuver; it must not limit or dictate when and where a force can go. This system must aid the commander's efforts to mass his firepower; to increase his ability to deliver the destructive blow, at the critical time. The system must also protect the force by not drawing attention to the fact that it exists. The system must minimize its emission of signals that can be detected and ensure that emitted signals cannot be exploited by the enemy.

3. The AirLand Battle Doctrine Tenets

The AirLand Battle doctrine is a formula for generating combat power. The doctrine is based on securing and retaining the initiative and exercising it aggressively to accomplish the mission. The objective of AirLand Battle is to impose our will on the enemy. The doctrine is based on four tenets which are as follows:

- initiative,
- agility,
- depth,
- synchronization. [Ref. 4:p. 14]

Initiative is the setting or changing of the terms of the battle by action. Initiative implies an offensive spirit or nature; it is a willingness to accept risk when the cir-

cumstances are favorable. Initiative is a constant effort to compel the enemy to conform to the commander's will. [Ref. 4:p. 15]

Agility is the ability to act faster than the enemy; it is being able to work inside or faster than his C2 process. Agility is necessary if the commander hopes to seize and retain the initiative. It permits the rapid concentration of strengths against weaknesses. For a commander to be 'agile' he must reduce 'friction' on the battlefield. Friction is, "...the accumulation of chance errors and confusion on the battlefield." [Ref. 2:p. 16]. It is, "...the force that makes the apparently easy so difficult. It is the product of the many small mistakes, delays, miscalculations, and conflicts that occur...." [Ref. 4:p. 8].

Depth is the extension of operations in space, time, and resources. Through operations in depth, the commander obtains space for maneuver, time for planning and time to acquire resources. The tenet of depth is applied when the commander plans to fight three battles simultaneously: the deep battle, the rear battle, and the close battle. [Ref. 4:p. 16]

Synchronization is the arrangement of battlefield activity in time, space and purpose to produce maximum combat power at the decisive point. Synchronization is both a process and a desired result. Synchronous activities produce synchronized operations which overload the enemy's ability to sense, decide, and act. Through synchronization, "...the enemy's tempo and cohesion are shattered. Once this is achieved the initiative is gained and the enemy will be presented with unexpected situations more rapidly than he can deal with them." [Ref. 5:p. 69].

Synchronization is the most difficult tenet to apply and the most difficult attribute to attain on the AirLand battlefield. It requires the commander to have knowledge of all forces that are operating in his sector, regardless of their relation to his command. This is necessary so all combat systems can function in harmony and fight as one cohesive force. This is also how fratricide on a complex and confusing battlefield will be avoided. If a commander cannot synchronize the activity of these forces in space, time, and purpose, his efforts under AirLand Battle will fail. [Ref. 4:p. 16]

The commander's AirLand Battle command and control system must embody the AirLand Battle Tenets. The system must increase the commander's ability to reach sound decisions by reducing uncertainty about the environment. It must reduce the 'friction' which is an inherent component of military operations. The command and control system must reduce the stochastic nature of combat operations by providing the commander with timely, accurate, and relevant information. The system must allow the

commander to confidently expand his operations in time and space while continuing to maintain positive control over his assets.

Synchronization of battlefield activity must be a paramount concern of the command and control system, "...a commander's focus must be oriented at all times to his ability to synchronize his forces. His command and control effort (system) is the primary means through which synchronization is achieved." [Ref. 5:p. 71]. The system must improve the commander's ability to concentrate the maximum amount of combat power at the most decisive point. Synchronization is the all essential tenet that the command and control system must enhance. It is the keystone upon which success on the AirLand battlefield rests. Without synchronization, a commander will not be capable of generating the combat power required to seize the initiative, apply agility, conduct operations in depth, and defeat a numerically superior force. To obtain synchronization the commander's C2 system must provide and present timely, accurate, and relevant information on all friendly forces operating in the commander's sector. With this information, a commander can fuse all of the friendly forces into a truly combined arms team, capable of fighting as one synchronized force.

4. The AirLand Battle Imperatives

The AirLand Battle Imperatives embody the principles of war in the doctrine. The AirLand Battle Tenets will characterize a successful operation but the AirLand Battle Imperatives are the essential elements that ensure success of an operation. A correlation exists between the Imperatives and the functions found in Lawson's command and control process model. In some cases this correlation is self evident and in others it is not. The commander's C2 system must embody these imperatives and through the C2 process must ensure they are applied. The Imperatives of AirLand Battle doctrine and their correlation with the C2 process functions are as follows:

• anticipate events on the battlefield;	SENSE
• conserve strength for decisive action;	PROCESS & COMPARE
• use terrain, weather, deception, and operations security;	PROCESS & COMPARE
• use combined arms, sister services, and allied forces to complement and reinforce;	EVALUATE
• ensure unity of effort;	EVALUATE
• concentrate combat power against the enemy's vulnerabilities;	EVALUATE
• understand the effects of battle on	EVALUATE

soldiers, units and leaders;

- designate, sustain, and shift the main effort; DECIDE
- press the fight; ACT
- move fast, strike hard, and finish quickly. ACT
[Ref. 4:pp. 22-26].

A C2 system that functions under the AirLand Battle doctrine must embody the offensive spirit of its tenets and must enhance the commander's ability to apply its imperatives. This system must perform the five functions outlined in Lawson's C2 process model. It must provide the commander with timely and accurate information on the battlefield and it must provide a display so the commander can visualize (SENSE) the events as they occur on the battlefield. The system should automatically and continuously update itself (PROCESS and COMPARE) thereby enabling the commander to designate (DECIDE) the most appropriate unit to assume a mission.

The AirLand Battle C2 system must not detract from the comander's efforts to press the fight or exploit the situation (ACT). The system must enhance unity of effort which is synonomous with synchronization and this goal must not be isolated to just one unit, but must be extended to adjacent units, to the other services, and to our allies. The AirLand Battle command and control system must be interoperable and capable of exchanging information with other C2 systems (EXTRANEOUS DATA).

5. Force Structure

The previous sections of this chapter addressed the AirLand battlefield and how combat power is generated and applied to make the battlefield more conducive to our operations and subsequent attainment of our goals. Before proceeding though, some important aspects about the force structure (resources) which supports the Army commander on the AirLand battlefield must be identified.

a. The Army of Excellence (AOE)

The Army of Excellence is the force structure which was developed to provide a viable and capable force to conduct combat operations under the AirLand Battle doctrine. It satisfied a need for a, "...fighter-heavy, more deployable force that could be delivered (to the AirLand battlefield) with minimum resources...." [Ref. 6:p. 1.3].

The AOE force structure realigned the resources available to form a more solid and versatile combat force capable of successfully executing the AirLand Battle doctrine on the modern battlefield. This realignment of resources has resulted in a complex force structure which provides a commander with a greater variety and capa-

bility for delivering destructive force to the battlefield than ever before. A commander is no longer just concerned with controlling infantry, armor, artillery, or cavalry. Today's commander must be capable of synchronizing the operations of ten combat arms or combat support organizations and eight combat support organizations. The commander must exercise command and control over highly mobile and fast moving ground and air forces functioning as one force in a combined arms team. He must have a C2 system that can handle the diversity of participants and information which this combined arms team will require and generate.

The AOE force structure is manpower lean and relies on technologically advanced weapon systems to compensate for its reduced size. Today's technologically advanced weapons systems are more accurate, lethal, and do provide greater amounts of firepower than in the past, but they are also more expensive. The result of increased monetary costs has been a reduction in the number of assets available. Commanders today are still expected to perform the same missions as they did in the past and they are expected to do it with fewer assets. To accomplish this, commanders must now disperse their limited numbers of men and equipment over greater areas. This concept of dispersal has resulted in an increase in the amount of area a unit must control. This situation is compounded by the fact that today's enemy (usually considered to be the Warsaw Pact) can also place greater amounts of lethal and accurate firepower on our forces and has not been constrained by monetary concerns of his nation.

Historically, dispersal of assets has been the manner by which commanders have coped with the increased lethality of modern weapon systems. Today's commanders are also using dispersal to reduce the possibility of detection, which reduces the possibility of becoming a lucrative target.

Figure 4 is a graphical display of how much acreage an infantry battalion has become responsible for over time as technology has improved weapons and commanders have dispersed forces. It is important to note that an anomaly exists between the size of an infantry battalion in 1865 and a current day AOE battalion. Both are purported to contain approximately 800 men but in an AOE battalion, only 468 are actually combatants (riflemen or antitank crewmen). The remaining 332 men are support personnel. [Refs. 7:p. 23; 8:p. 2.14]

b. Command and Control on the AirLand battlefield

As dispersal of units and the complexity of the force structure has increased, the commander's ability to effectively command and control his forces has decreased.

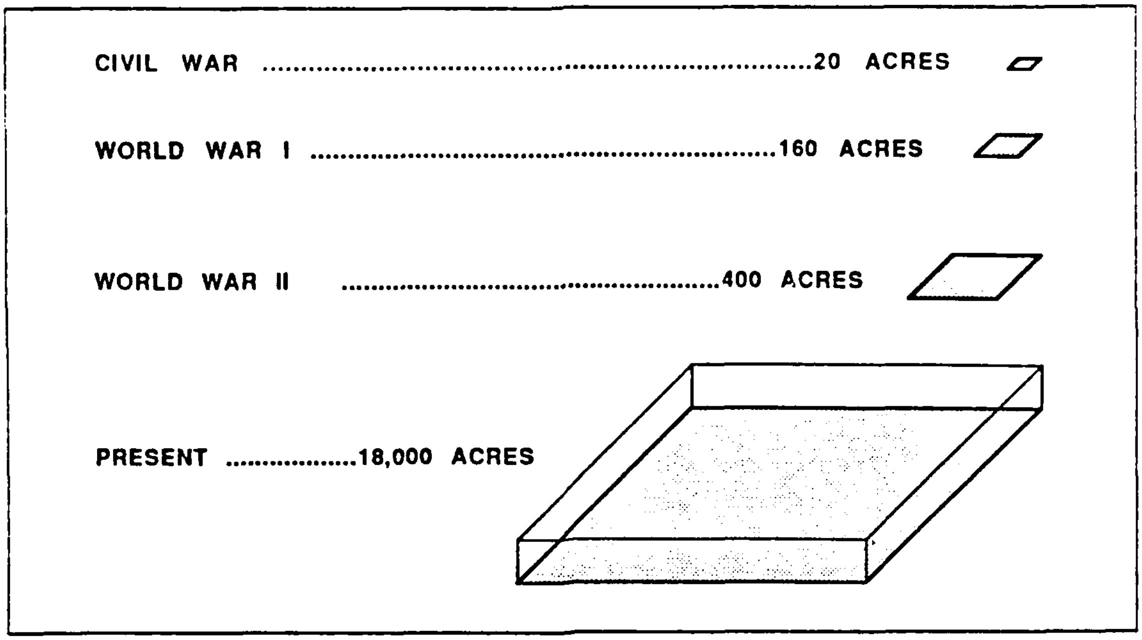

Figure 4. Historical Dispersion and Coverage

Where a commander once executed positive control over his forces, he now must rely on procedural control. Procedural control infers a reliance upon previously arranged procedures or orders. The commander must rely on his subordinates and must believe that they understood the intent of his order and are executing it properly. In this case the commander will only know what his subordinates tell him through reports that are normally filed in accordance with standard operating procedures (SOPs).

Historically, positive control inferred the commander had the ability to see and influence the entire battlefield from his command post. Today positive control infers a commander, using electronic devices, can automatically acquire information on the battlefield situation and can apply effective command and control from his command post. If a commander had a C2 system that provided positive control, the commander would not have to rely on his subordinates to report their actions and the commander would be able to see whether the intent of his order was understood and whether it was being executed. To a degree, positive control reduces the subordinate's responsibility to be part of the commander's 'SENSE' function in the C2 process and it allows the subordinate to apply his time and energy to other critical tasks (e.g.: seizing the initiative). With positive control the commander will be more capable of sensing and evaluating the situation from his command post.

With only procedural control, the commander is operating with a less effective command and control system. The commander is relying on his subordinates to see and, more importantly, to report the situation. The subordinates' ability to do this have a direct influence on a commander's ability to generate combat power, to ensure unity of effort, and to synchronize the activities of his units in time, space, and purpose.

The commander on the AirLand battlefield must have a C2 system that employs a mixture of positive and procedural control. Positive control should be the primary mode of operation and procedural control should be the alternative or back-up.

For a commander to maximize his overall force effectiveness at the decisive point, he must know: where his units are; what they believe their mission is; what their tactical posture is; and what their operational readiness/status is. As a minimum, the AirLand Battle command and control system must provide the commander with this information.

6. The Seven Command and Control Actions

The Army has developed it's own version of the Lawson's command and control process model. The Army's model is based on the AirLand Battle doctrine and the requirements it places on a commander to:

- simultaneously fight three battles, on a three dimensional battlefield;
- be constantly alert for chances to seize the initiative;
- think and act faster than his opponents;
- bring maximum combat power to bear at the critical point;
- force his will on the enemy.

To assist the commander in accomplishing these tasks, the Army's C2 model has identified seven command and control actions. These actions correspond directly to the five functions found in Lawson's model. The seven actions and the corresponding function are listed below:

1. see the situation;	SENSE
2. evaluate the situation;	COMPARE
3. develop the plans;	DECIDE
4. allocate resources to support the plans;	DECIDE
5. coordinate the resources;	DECIDE
6. fight the battles;	ACT
7. sustain the force [Ref. 9.:p. 18].	ACT

Of the seven actions, 'seeing the situation' and 'evaluating the situation' can be considered the most important. These two actions are the initial steps in any decision making or problem solving process. If a commander or staff does not see or sense a change in the environment, he/it will not be capable of accurately evaluating the situation. If either of the first two steps are not executed properly, the remaining five steps will be an exercise in futility.

The commander's ability to 'see the situation' is driven by the Army's ability to gather information on friendly and enemy forces. The enemy does not openly and freely invite the Army to gather information on it and that information which is gathered, is often clouded by the enemy's use of deception. The enemy's situation is a perceived one. It may be very accurate or it may be totally inaccurate. The commander has little capability to control this fact.

The commander's ability to 'see the friendly situation' is driven by his subordinate commander's and staff's ability to provide desired information. This information should be more accurate because the element of deception is absent. This is not always the case because the commander must rely on his subordinates to manually generate this information.

The current AirLand Battle C2 system is based on procedural control. The system is manpower intensive and slow. It relies on people to generate, encrypt, exchange, decode, interpret, post, and analyze information. This process involves seven steps and may be reiterated at many echelons of command before the information reaches the commander or staff that needs it. This means the probability of errors entering the information increases and the timeliness of the information is degraded.

The commander and staff must be provided information that is timely, accurate and of high resolution. The commander and staff must have a C2 system that will automatically collect, verify, fuse, filter, disseminate and display information in a usable format. If the commander and staff have a robust and versatile C2 system as described, this seven step process will be reduced to two steps, interpret and analyze. This reduction of workload means the commander and staff will be able to direct more time to interpreting and analyzing information and on developing better plans. This redirection of time and effort will enable the commander to seize the initiative, to be more agile than his opponent, to synchronize activities on the battlefield and to strike in depth to accomplish his assigned mission.

7. The Command, Control and Subordinate System

The Command, Control and Subordinate System (CCS2) architecture integrates the C2 systems of five battlefield functional areas into the Army's Tactical Command and Control System (ATCCS), an element of the Army's Command and Control Master Plan (AC2MP). The CCS2 assists commanders and staffs in effectively transferring and organizing information which supports operations on the AirLand battlefield. [Ref. 10:p. 8]

The CCS2 is structured around five battlefield functional areas (BFA). Each BFA consists of one or more of the Army's basic branches. The list which follows identifies the five battlefield functional areas and their respective branches.

1. Maneuver:
   - Infantry (Close Combat Light),
   - Armor (Close Combat Heavy),
   - Aviation,
   - Engineers,
   - Signal Corps,
   - Chemical Corps,
   - Military Police.
2. Fire Support:
   - Field Artillery.
3. Air Defense:
   - Air Defense Artillery.
4. Intelligence and Electronic Warfare:
   - Military Intelligence.
5. Combat Service Support:
   - Medical Service Corps,
   - Transportation Corps,
   - Ordinance Corps,
   - Quartermaster Corps,
   - Staff Judge Advocate Corps,
   - Adjutant Generals Corps,
   - Finance Corps,
   - Chaplains Corps. [Ref. 9]

All of the missions and operations at the tactical level fall under one of these five functional areas. All of the plans a commander develops or executes will be influenced in some way by these functional areas and will require interaction between most if not all of the branches. [Ref. 10] Figure 5 depicts the CCS2 architecture [Ref. 10:p. 4.9].

The architecture is hierarchical in nature, extending from corps down to the lowest tactical levels. At each echelon the architecture is replicated and the echelons are linked through the functional area commanders. Each functional area commander at a specific echelon is responsible for receiving and processing information from higher and lower echelons within his functional area. The functional area commanders then disseminate this information, as appropriate, to the other functional areas on their respective level or echelon. Figure 6 displays the hierarchy which exists in the CCS2. [Ref. 9:p. 22]

The architecture is linked or supported by a communications network which consists of three components. These components are:

- the combat radio system;
- the area common user system;
- the area data distribution system. [Ref. 9:p. 9]

Figure 7 reflects how these systems not only interface with all five of the CCS2 functional areas but also interface with each other. The network's ability to interface allows a functional area commander to communicate both horizontally and vertically throughout the architecture. [Ref. 10:p. 9]

The CCS2 architecture supports the commander's decision making process by establishing baselines for coordination and communications within and across BFA C2 systems. As future BFA C2 systems are fielded, the CCS2 will provide a means of identifying requirements for connectivity. Future C2 systems must be fully integrated into CCS2 and should employ ATCCS common hardware and software to ensure maximum interoperabilty. The CCS2 is the vehicle that will enable commanders and staffs operating on the AirLand battlefield to realize the full potential of automated C2 systems. This architecture will enhance their ability to exchange, receive, process, and filter information. Automation, in conjunction with the CCS2, will enable a commander to exercise positive control over his forces on the AirLand battlefield.

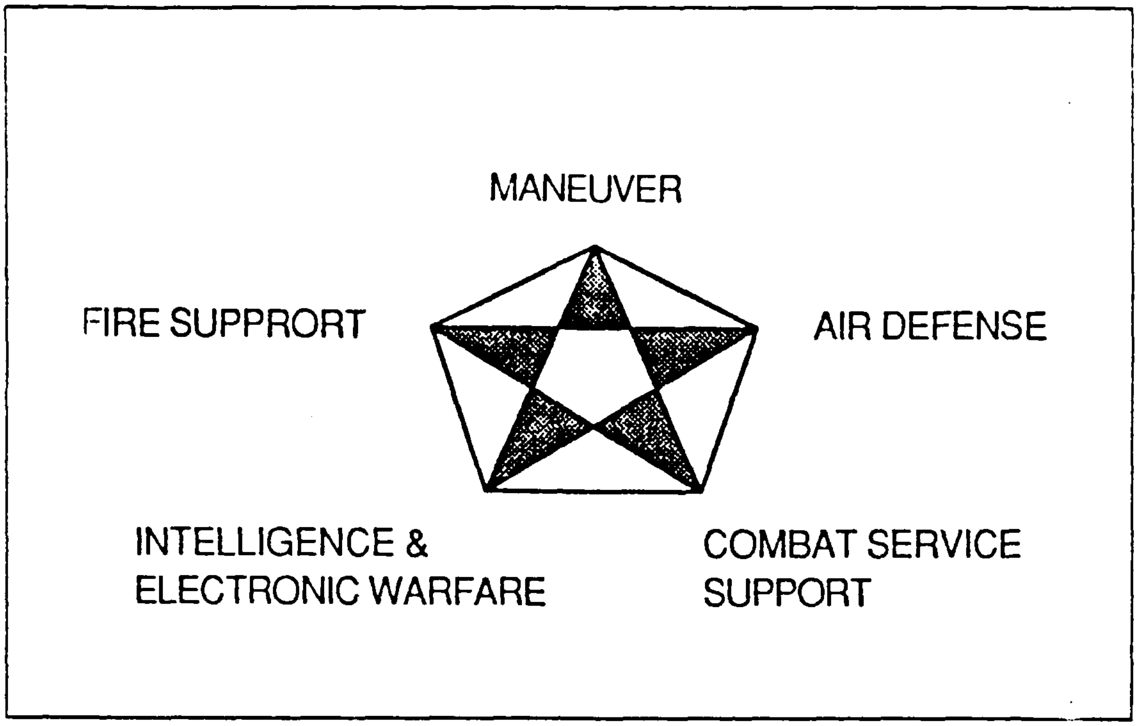

Figure 5. Command, Control and Subordinate System (CCS2)

8. Materiel

a. Combat Systems

As previously stated, the weapon systems in the U.S. Army are the most lethal and most mobile that it has ever possessed. A commander today has phenomenal amounts of destructive capability at his disposal. Systems such as the Multiple Launch Rocket System, the M-1 Abrams Tank, and the Patriot Air Defense System are at the forefront of their technological communities. The Army intends to continue to improve the capabilities of combat systems so as to meet and defeat the threat it faces.

b. The Command and Control System

The state of the Army's C2 system is bleak. As previously stated, the system is a manual system that relies on procedural control measures to generate information and antiquated procedures to display and disseminate it. In a slow moving, relatively static scenario, with units operating over a very limited area, this system might function adequately. Under the concept of AirLand Battle doctrine, battles will rage across the full depth of the battlefield and success will be measured in speed, synchronization, agility, initiative, and action. A manual C2 system will not be capable of re-

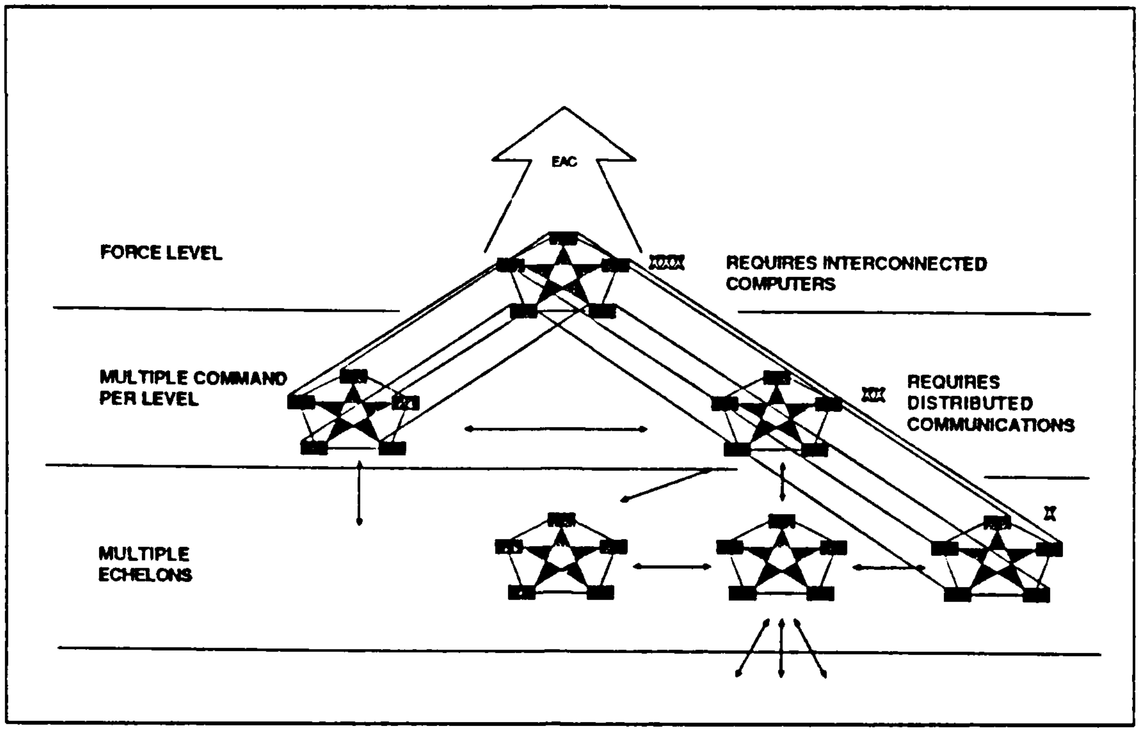

Figure 6. The CCS2 Architecture Hierarchy

sponding to the commander's need for information, it will become flooded with information and chaos will ensue.

9. The Threat

The U.S. Army must be prepared to conduct combat operations across a wide spectrum of conflicts, ranging from high to low intensity. The levels of intensity are meant to describe and limit the use of war or warfighting assets. Each level of intensity has a distinct definition which embodies specific characteristics that differentiates it from the others. The definitions for high, mid, and low intensity conflicts are as follows:

- High Intensity Conflict: "...war between two or more nations and their respective allies, if any, in which the belligerents employ the most modern technology and all resources in intelligence; mobility; firepower (including nuclear, chemical, and biological weapons); command, control, and communications; and service support." [Ref. 11:p. 14].
- Mid Intensity Conflict: "...war between two or more nations and their respective allies, if any, in which the belligerents employ the most modern technology and all resources in intelligence; mobility; firepower (excluding nuclear, chemical, and biological weapons); command, control, and communications; and service support for limited objectives under definitive policy limitations as to the extent of de-

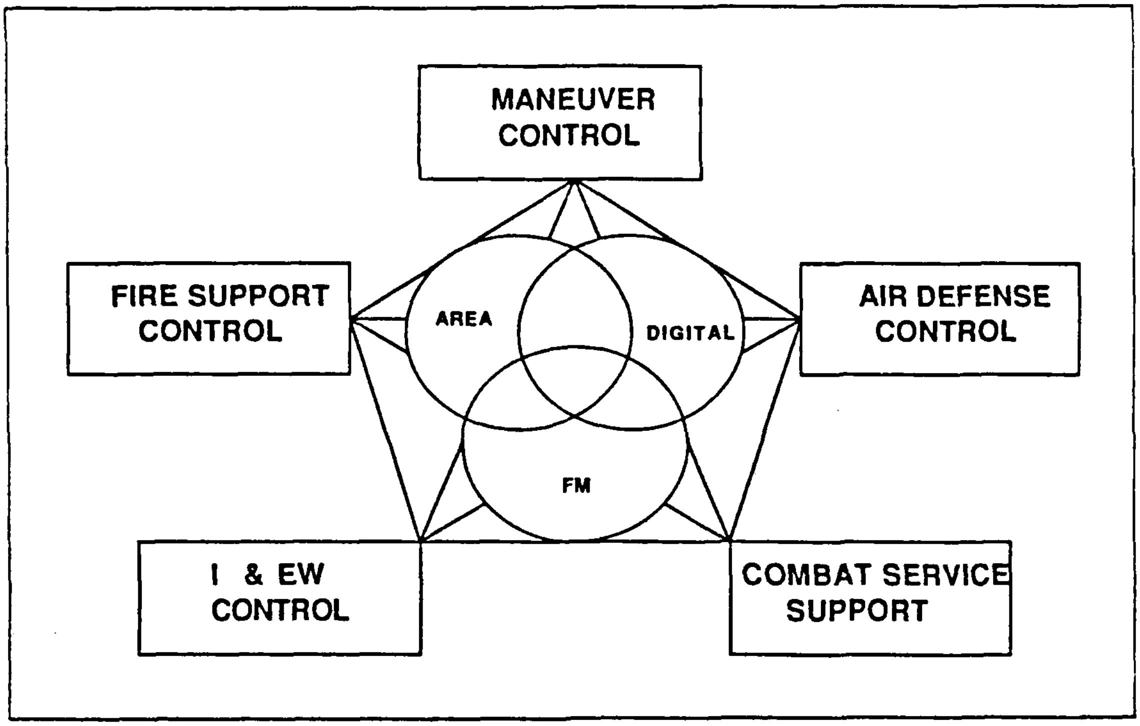

Figure 7. The CCS2:Communications Network Interface

structive power that can be employed or the extent of geographic area that might be involved." [Ref. 11:p. 14].

- Low Intensity Conflict-Type A: "...internal defense and development assistance operations involving actions by U.S. combat forces to establish, regain, or maintain control of specific land areas threatened by guerrilla warfare, revolution, subversion, or other tactics aimed at internal seizure of power." [Ref. 11:p. 14].
- Low Intensity Conflict-Type B: "...internal defense and development assistance operations involving actions by U.S. advice, combat support, and combat service support for indigenous or allied forces engaged in establishing, regaining, or maintaining control of specific land areas threatened by guerrilla warfare, revolution, subversion, or other tactics aimed at internal seizure of power." [Ref. 11:p. 14].

For the purposes of this discussion two assumptions will be made:

- High and mid intensity conflicts share sufficient common characteristics to permit combining them into one threat category to be known as High to Mid Intensity Conflict.
- The two types of low intensity conflict share sufficient common characteristics to permit combining them into one threat category to be known as Low Intensity Conflict (LIC).

As the level (intensity) of the conflict changes so will the threat forces faced by the U.S. Army. This next section will provide a superficial examination of the threat U.S. combat forces can expect to face in future high to mid intensity and low intensity conflicts. This examination will consider the following three areas: doctrine, force structure, and materiel. For a more in depth examination of the threat, the reader is referred to the AC2MP (S), Volume II, 1 September 1987; FM 100-2-1, SOVIET ARMY OPERATIONS AND TACTICS; and FM 100-20, LOW INTENSITY CONFLICT.

a. High Intensity Conflict

High to mid intensity conflicts are considered to be the most severe form of conflict the U.S. Army is likely to be involved in, in the foreseeable future. High to mid intensity conflicts are typically thought of as a joint and combined operation in a European scenario where a base of operations exists and lines of communication are established. Under this scenario the threat forces of the Warsaw Pact present the most serious opposition. Combat under high to mid intensity will be characterized by extremely rapid, continuous operations, employing mechanized ground forces and large amounts of air power on an extremely fluid battlefield. The employment of extremely accurate and lethal, high technology weapons will be commonplace. Electronic warfare will be employed extensively, as will nuclear, biological, and chemical weapons.

b. Low Intensity Conflict

Low intensity conflict is a less severe form of conflict but one in which the U.S. Army has a greater probability of becoming involved. It focuses primarily on developing, third world nations and the need for U.S. forces to assist in conducting internal defense operations, counter insurgency operations, and peace keeping missions. These operations might require the rapid deployment of a force to a remote theater of operations (a non-European scenario) where the force would have to establish a base of operations and where lines of communication do not currently exist. Low intensity conflicts are typically thought of as crisis or contingency operations or rapid response strikes that result from an unforseen event which threatened U.S. citizens or interests. A most recent example of this was the United States intervention into Grenada (Operation Urgent Fury) in October of 1983. [Ref. 11]

Low intensity conflicts will be characterized by highly lethal, intermittent combat actions. Clear and distinct lines of combat or fronts will not exist and U.S. forces will be widely dispersed to control more terrain and to be better prepared to immediately respond to contingencies.

As previously stated, high to mid intensity conflict is the most severe threat scenario the U.S. Army expects to face. Its probability of occurring is less than that of low intensity conflicts, which are less severe. Figure 8 illustrates the relationship that exists between the probability of occurrence and the severity of each category of conflict.

c. Doctrine

(1) High Intensity Conflict. The threat forces of the Warsaw Pact adhere to a doctrine based on mass, speed, momentum, and dynamic action. The threat will launch many attacks across a wide front in an effort to force a penetration in our defenses. If an attack succeeds, the threat will attempt to exploit the situation by concentrating maximum force on the breach in an effort to force massive formations through it and into our rear areas.

As the threat conducts operations to the immediate front, other threat ground and air forces will conduct simultaneous operations in our rear areas. These deep operations will be launched at high value targets (e.g.: logistic centers, nuclear storage facilities, air bases) in an effort to disrupt our continuity of operations. The Warsaw Pact nations have identified command and control centers as high value targets and their doctrine requires,

> "...the rapid location and identification of command and control elements....once pinpointed, command posts will be exploited (by electronic warfare) until they can be destroyed by tube or rocket launched artillery, air delivered ordinance, or rear area unconventional warfare parties." [Ref. 12:p. 3].

(2) Low Intensity Conflict. The threat forces in low intensity conflict will most likely consist of regular or irregular forces from third world nations, guerrilla forces, or terrorist groups. The threat will not attempt to maintain constant contact with U.S. forces but will strive to attack and destroy high visibility or high value targets when the situation is most advantageous. These forces will not possess the level of training or proficiency expected of the threat in a high to mid intensity conflict but they will be more familiar with the battle area and will use this advantage to maximize their limited capabilities. [Ref. 11]

d. Force Structure

(1) High to Mid Intensity Conflict. The Warsaw Pact nations are organized into highly mobile armored and mechanized forces supported by vast amounts of artillery and aviation assets. The threat is organized and trained to function under a combined arms concept. They have been, and will continue to be, a numerically superior force. The threat's massive force structure allows them to simultaneously conduct nu-

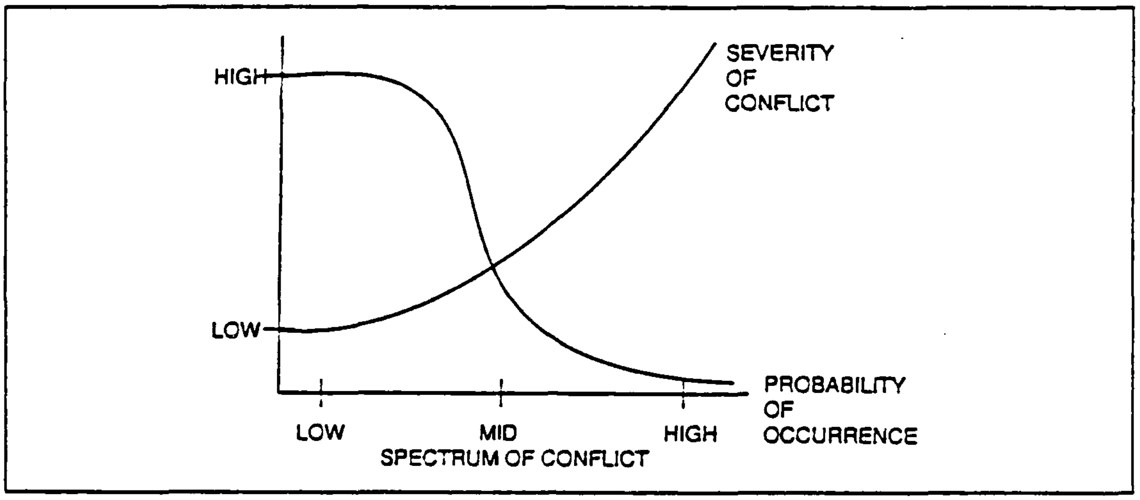

Figure 8. Probability vs. Severity of Potential Conflict Type

merous, large scale, and highly lethal offensive operations. Their mobility permits them to quickly and efficiently shift their forces about the battlefield to exploit any advantage. The threat possesses extensive electronic warfare, NBC, and intelligence capabilities. They function under a well established, highly centralized command and control system that applies techniques of operations analysis and automation to the battlefield. [Ref. 13]

(2) Low Intensity Conflict. The threat to be countered in a low intensity conflict is expected to be a lightly or non armored/mechanized force. It will consist of infantry forces supported by light artillery and no or limited aviation assets. This is not to infer that the threat will not be a formidable one but it is not envisioned to possess the capabilities of that to be faced in a high to mid intensity conflict. It is not expected that the threat would possess any nuclear capabilities but may possess limited electronic, biological and chemical warfare capabilities. Its organic capability to collect intelligence material would most likely be limited to human intelligence (HUMINT) and some communications intelligence (COMINT).

e. Materiel

(1) High to Mid Intensity Conflict. The Warsaw Pact nations possess a vast array and number of modern weapon and combat support systems capable of being employed on the modern battlefield. These systems are highly mobile and incorporate a level of technology that challenges our technological advantage. The threat has made

and continues to make improvements in weapon and combat support systems, specifically in the areas of mobility and command and control. [Ref. 14:p. 1-2]

(2) *Low Intensity Conflict.* The threat in a low intensity conflict will most likely possess export variants of equipment made by the Warsaw Pact nations, the United States, or one of the major arms exporting nations (e.g.: Peoples Republic of China, Peoples Republic of North Korea, France). Although this equipment may be of inferior quality or outdated when compared to that found in a high to mid intensity conflict, it nonetheless presents a formidable and lethal threat to the force that must counter it. As major world powers develop and improve their current weapon and combat support systems their outdated versions will enter the foreign military sales arms market and will become available to developing nations. The potential acquisitions of these systems by third world nations can be viewed as an enhancement to the threat those nations present.

f. Threat Summary

The potential threat the U.S. Army must be prepared to counter is varied. The threat may possess weapon and combat support systems that are comparable to present day American systems. The threat may come from an area where the U.S. Army has operated extensively; where the support base is in position and the lines of communication are established; or it may come from a region where no U.S. force has ever conducted operations; where there is no local support base and where the lines of communication are extended. U.S. forces will use dispersal as a means of ensuring survivability and maintaining control of terrain.

Regardless of the threat, the commander and his staff require a C2 system that will be responsive to his/their needs and that cannot be exploited by the enemy. The system must be deployable, capable of supporting worldwide operations and interoperating with the C2 systems of our allies and the other U.S. services.

10. The Combat Environment

A final aspect of the AirLand Battle environment the commander must consider is the combat environment. This environment includes such topics as:

- the commander's assigned mission;
- the time the commander has available to accomplish this mission;
- the actual terrain the commander will conduct operations on;
- the constraints that may limit the operation;
  - budgetary constraints;

- logistic constraints;

- the development of future concepts and systems.

The combat environment embodies many of the elements that Lawson's model refers to as extraneous factors. These factors cannot be totally controlled by a commander or staff but they must be monitored and considered when decisions are being made. They must enter the C2 process at some point. The following section will provide a brief overview of these factors and will provide an insight into their importance to the C2 process.

a. Mission

The mission is the goal towards which the commander and staff strive. It will have a direct influence on a commander's ability to exercise effective command and control. The commander must have a versatile C2 system that is capable of configuring itself to support any mission or contingency.

b. Time Available

Time on the battlefield is a precious commodity that a C2 system can ill-afford to waste. A commander only has a given amount of time from receipt to execution of a mission order. During this period his staff must gather information, generate alternative courses of action, present those courses of action for evaluation, receive a decision, prepare and distribute orders, and allow sufficient time for subordinates to repeat this process at their level of command.

The commander and staff must have a C2 system that is efficient and that can save time by streamlining this process. Automation is the key to providing such a system. If a commander had a C2 system that could continuously and automatically generate, receive, store, and disseminate information the amount of time his staff requires to complete its cycle would be greatly reduced.

The commander's C2 system should also be capable of presenting the maximum amount of useful information in the shortest time possible. This could be accomplished by providing the commander a display that at a glance could provide him situational information on all the units operating in his sector. From this information he could quickly assess the situation and decide who is capable of assuming what mission.

c. The Terrain

Terrain encompasses all aspects of the natural environment such as: weather, the relief and elevation, hydrology, soil composition, obstacles, etc. The C2

process must consider the characteristics of the natural environment when comparing and evaluating alternative courses of action.

The C2 system must also consider the natural environment in which it will function. Will relief features pose a problem to line of sight dependent systems? Will the soil support the weight of the C2 system's prime mover? Will the atmospheric properties of the region effect the C2 system's electromagnetic signals? All of the concerns terrain poses to a planner of maneuver operations must be applied to C2 systems if those systems are going to support the planned operations.

d. Constraints

Constraints are limitations or restriction placed on a person, activity, or system. Two major constraints that commanders face today are budgets and logistics.

(1) Budgetary Constraints. The current trend in fiscal spending to support military equipment, manning, and operations is downward. Commanders cannot expect the recent surge in spending to continue and must anticipate cutbacks in future allocations. These cutbacks may come in manpower or equipment. A cutback in either, without a reduction in mission load will lead to greater dispersion on the battlefield. An additional increase in dispersion would exacerbate the commander's currently tenuous ability to exercise C2 on a highly lethal and rapidly changing battlefield. To compensate for problems caused by decreased military spending, and to enhance the commander's ability to exercise command and control, the Army must develop an economical C2 system that can support the operations of a widely dispersed force.

(2) Logistical Constraints. Regardless of the area of operations, logistics will always be a concern in the C2 process. A superior system can become a white elephant, an albatross around the commander's neck, if the logistics system cannot provide the support it requires. A C2 system must not be logistically intensive. It must not require or place extraordinary demands on the logistics system.

e. The Future

A commander and his staff must always think to the future as they apply the C2 process. They must consider how today's actions will drive and determine tomorrow's actions. This is also the case with doctrine and C2 systems that will support operations under that doctrine. AirLand Battle is the doctrine the U.S. Army will employ in today's wars to meet our national objectives. AirLand Battle Future is an extension of the AirLand Battle doctrine through the year 2004. The next section of this

paper will discuss how AirLand Battle Future will generate requirements for a new C2 system to support operations on the future AirLand battlefield.

(1) *AirLand Battle Future.* AirLand Battle Future (ALB-F) embodies all of the fundamentals of AirLand Battle but also, "...emphasizes the joint and combined nature of modern warfare and the need to maximize the full potential of U.S. and allied forces in a unified effort." [Ref. 15:p. 2].

AirLand Battle Future, like AirLand Battle, is a doctrine based on maneuver warfare. It sees the Army fighting in a scenario where the adversary has a numerical advantage. To defeat the foe the Army must, "...throw the enemy off balance with a powerful blow from an unexpected direction, follow-up rapidly to prevent his recovery and continue operations aggressively." [Ref. 15:p. 3]. The operations, "...must be rapid, unpredictable, violent and disorienting, and the pace must be fast enough to prevent him (the enemy) from taking effective counteraction." [Ref. 15:p. 4].

To support these operations, AirLand Battle Future requires operational and tactical plans that stress flexibility; that create opportunities to capitalize on the adversary's weaknesses; that ensure synchronization of joint and combined operations; and that are precise in nature. To be flexible, capable of changing; to capitalize on weaknesses; and to ensure synchronization of forces; a commander must have a command and control system that provides him automated, timely, accurate, and relevant information. This system must interface with or be interoperable with those systems used by other services and by our allies.

The Army under AirLand Battle Future must organize as a maneuver force. This force must consist of, "...agile, powerful, self-sustaining tactical units that can operate and survive, independent of ties to a fixed sustaining base, other like units and higher headquarters." [Ref. 15:p. 15]. This force must be, "...mobile enough to concentrate rapidly from dispersed locations, engage the enemy with violent attacks to shock, paralyze or overwhelm him quickly and then rapidly disperse to avoid enemy counterattack." [Ref. 16:p. 16].

To succeed under AirLand Battle Future doctrine, the Army must embark on an evolutionary process which will transform our current organizations into maneuver forces. The AirLand Battle Future Concept Statement, dated 16 June 1987, has identified four major goals which this evolutionary process must strive to attain. These goals are as follows:

- deployability,

- reliable and efficient systems,
- complementary systems,
- near real time command and control.

The Concept Statement refers to deployability in the following context, "...we must improve our ability to move an entire force globally and within a theater on an order of magnitude higher than current capabilities." [Ref. 15:p. 17]. Deployability is a function of weight, volume, and airlift capability. All future systems must consider these factors to ensure the deployabilty of the force, which the system supports, is maximized. The optimum design of a system is one that is self-deployable or one that is wholly contained in a self-deployable system.

Reliable and efficient systems are referred to as, "...(systems) must be improved so tactical units can operate autonomously for extended periods." [Ref. 15:p. 17]. Systems must be operational immediately upon entering a theater of operations. Systems cannot require excessive amounts of setup work, ancillary equipment, or installation time. Once a command post has been established all command and control systems must become operational. All systems must be reliable and dependable in any environment, on any terrain. Any supporting component of a system must be easily replaceable and not so critical that its loss means the total system becomes non-operational. Redundancy and graceful degradation must be typical characteristics of all future command and control systems.

The Concept Statement recognizes the importance of jointness and combined forces through discussions of complimentary systems which state, "...we must improve our procedures for the complimentary use of acquisition and attack resources of other services, higher Army echelons and Allies." [Ref. 15:p. 17]. Command and control systems must interface, either directly or through common hardware and software, with the overall Army Tactical Command and Control System to ensure maximum exchange of information. The Army must develop economical, interoperable systems which will use common hardware and software so the transfer of information between the other services and our allies is maximized.

The Concept Statement clearly dictates a need for a near real time command and control system when it states, "...we must continue to develop command and control systems which allow us to receive and disseminate information to all of our formations in near real time." [Ref. 15:p. 17]. These systems should be automatic or transparent to all users. Status and location reports should be sent to a command and

control center as they occur without requiring any action from the users. Information should be received and stored in a database system and displayed on a tactical operations screen. The database and tactical operations screen should be continuously and automatically updated as changes are received. Lower echelon command elements should pass data vertically and horizontally via the Command, Control and Subordinate System and commanders receiving this data should be capable of displaying it on their tactical operation screens.

Improved command and control systems will be essential if AirLand Battle Future doctrine is to succeed. Commanders under AirLand Battle Future will have to control many small, highly mobile, autonomous forces that are widely dispersed on a dynamic battlefield. The attainment of synchronization among these units will be even more complex and challenging than it is today. If the AirLand Battle Future commander can effectively command and control these units, he will be able to control the tempo of operations, establish the terms of the battle, impose his will on the enemy, and defeat the enemy at the place and time he chooses.

11. Baseline Deficiencies

Thus far, this chapter has examined command and control under the AirLand Battle doctrine from the context of the Lawson command and control process model. The examination has produced a list of significant deficiencies which categorize the current methods for exercising command and control as inefficient. The identified deficiencies follow:

- Timeliness: The current C2 system is a manual, manpower intensive process that requires excessive amounts of manual manipulation of data. This is a slow process which could be avoided through the use of automation. With automated devices information could be continuously and automatically generated, transmitted, received, stored, and disseminated. Information is a time sensitive commodity that must be available when it is needed. Commanders on the AirLand battlefield cannot wait information to be generated.

- Data Processing: The current C2 system is manual and all of its data processing is done by hand. This process is slow and has great potential for allowing errors to enter the information. The system is not capable of quickly answering ad hoc questions that might arise. The system's database system consists of paper, charts, and status boards. The method for exchanging information between C2 systems is known as transcribing or copying desired information by hand.

- Communications: There is no direct interface between today's C2 systems and the communications systems that must support them. Information must be relayed with a man in the loop. One command center cannot received information from another without a man initiating the request and another man responding.

- Intelligence Collection/Processing/Dissemination: This process, which occurs at all levels of command is not timely and requires the submission of a manually prepared report that may or may not contain accurate information due to a requirement for a man to initiate it.

- Display: The current system relies on various maps, overlays, and charts to present information on the same units. To determine where a unit is; what its strength is; and what its situation is; a commander might have to refer to three different charts or maps. This is not an efficient system. An excessive number of displays means that when time is short some chart is going to be overlooked and some critical piece of information is not going to be considered.

- Position Reporting: The current system relies on maps, compasses, and the ability of a soldier to properly use them to determine and report his position. This process takes time and because it depends on a man, is only as reliable as that man.

- Procedural Control: The system relies on the subordinate to perform the sense function for the commander. If the commander cannot rely on his subordinate to perform this function adequately the commander will have to do it himself. This usually requires him to leave his command post. By doing this, the commander has denied himself what few assets he has to effectively exercise command and control.

12. Initiatives

The current command and control system will not adequately keep pace with the needs of the commander on the modern AirLand battlefield nor will it be capable of smoothly transistioning to the battlefield of AirLand Battle Future. The Army has recognized these facts and to correct the previously cited deficiencies has embarked on a series of initiatives that will remedy the dilemma. Listed below are some of the more important initiatives:

- The Army's Command and Control Master Plan: This document establishes a baseline requirement for all future C2 systems.

- The Command, Control and Subordinate System: This is the architecture that will integrate all of the C2 systems from the various battlefield functional areas into one composite system known as the Army's Tactical Command and Control System. It also establishes the baseline for connectivity between the battlefield functional areas.

- The Army's Tactical Command and Control System: This is a family of interoperable C2 automated systems that incorporate common hardware and software to collect, manipulate, distribute information/data, and process data within and among the various battlefield functional areas.

- Communications: The Army is currently developing, procuring, and fielding three new families of communication networks to support the C2 process. These include the SINCGARS family of radios, the Mobile Subscriber Equipment (MSE) for area communications, and the Digital Data Distribution Network. These systems will provide the mediums for exchanging information across and throughout the battlefield functional areas.

- Information Generation: The Army is currently conducting limited development of automated C2 systems that will be information generators on the battlefield. These systems are intended to free the subordinate from having to process periodic status reports. One such system under development is the Inter-Vehicular Information System (IVIS). [Ref. 17]
- Battlefield Displays: As part of the ATCCS, the Army is considering the integration of large screen battlefield displays into the C2 centers. These screens would replace the current system's maps and charts.

These initiatives are a start but they are not the final solution. The Army must look to automation and display systems that will provide maximum information with minimum expenditure of time or resources. The weapon system operator on today's AirLand battlefield will not have time to prepare reports if he is expected to fight outnumbered and win. The last section of this chapter will cite two needs that have not been satisfied by the ongoing initiatives.

13. The Need

Sun Tzu is quoted as saying, "...if you know the enemy and know yourself, you need not fear the result of one hundred battles. If you know yourself and not the enemy, then for every victory gained you will also suffer a defeat. If you know neither the enemy nor yourself, then you will succumb in every battle." [Ref. 5:p. 76]. Sun Tzu's intent is to say that knowledge is the key to success on the battlefield and this point is as true today on the modern AirLand battlefield as it was in his ancient time. To know the enemy, the Army has developed the All Source Analysis System (ASAS). This intelligence system is the focal point for all intelligence data that is generated. It uses the CCS2 and the various communication networks to collect and disseminate intelligence information.

If the ASAS in conjunction with the CCS2 and various mediums of communication can satisfy the Army's need for information on the enemy, then what system provides the commander information on his forces? The answer to this question is the present day procedural command and control system. As previously discussed, this system is not timely, not accurate, and not reliable. It cannot provide the commander the information he needs to exercise effective command and control on the AirLand battlefield.

The Battle of Gettysburg (1-3 July 1863) provides a historical example of a procedural command and control system that failed to provide the commander the information he needed. The system's reliance on a subordinate's actions resulted in the defeat of the Confederate forces. One can only wonder what the outcome of the battle

would have been if General Lee, the commander of the Confederate forces, had been able to exercise positive control over General Stuart's cavalry. For the first two days of that battle and the previous five days, General Lee had no contact with nor any idea as to the whereabouts of Stuart's force.

On 23 June 1863, General Lee directed General Stuart to move his forces north of the Potomac River into Maryland as quickly as possible. General Lee intended to issue further orders once Stuart's forces had completed the move. General Stuart misunderstood General Lee's intent and proceeded to lead a 5000 man force on an uneventful expedition that lasted until 2 July 1983. [Ref. 18:pp. 26-116]

If General Lee had been able to monitor Stuart's activities, he would have known that Stuart had not understood the intent of the order. He would have realized that Stuart's forces were not contributing to the battle and he could have issued directives to correct the situation. If Lee had the capability to exercise positive control over Stuart, he could have synchronized the battle and brought his maximum combat power to bear on the enemy at the critical time. If this had happened, the battle of Gettysburg might have been a victory for the South and history as we know it today might be quite different.

The ability to have information is not sufficient to ensure victory. The commander must be able to quickly and efficiently apply this information to the C2 process. Another of Sun Tzu's principles states, "Speed is the essence of war. Take advantage of the enemy's unpreparedness; travel by unexpected routes and strike him where he has taken no precautions." [Ref. 2:p. 4]. Sun Tzu's principle is not limited to physical combat but extends to the C2 process where a commander must possess the ability to make decisions and act faster than his opponent; to take advantage of his opponent's unpreparedness; and to operate within his opponent's decision cycle. Modern history's most recent example of this is the Second World War.

> "In the German blitzkrieg of 1940, the German army's ability to paralyze the Allied forces' decisionmaking process was not based solely on the increased speed of the mechanized formations. It was based primarily on the ability to see the battlefield more clearly, make quick decisions, exploit opportunities, and disseminate instructions and create conditions which made it difficult for the French and British armies to identify and respond rapidly to the threat. This decision making time differential was what created the Allies' paralysis." [Ref. 19:p. 34].

AirLand Battle and AirLand Battle Future are doctrines dependent on knowledge and speed. Under these doctrines, the commander is tasked to sense, process, compare, decide, and act faster than his opponent. To accomplish this the AirLand

Battle commander, from battalion to division, must be supported by a very robust command and control system. Today's AirLand Battle commander and tommorow's AirLand Battle Future commander, must have a stand alone command and control system that:

- automatically and continuously generates, processes, stores, and disseminates near real time information on friendly forces;
- integrates friendly information with enemy information on a large screen display system that can:
  - display the AirLand battlefield in sufficient width and depth to allow the commander to visualize the three simultaneous operations he is tasked to conduct;
  - display not only forces on the ground but elements operating in the third dimension of AirLand Battle, the air;
  - provide the commander the capability to vary the resolution of his battlefield display to focus his attention at the critical points as the situation changes.

If the commander on the AirLand battlefield can harness the technology of automation he will be able to use it as a force multiplier to synchronize his combat power in time, space, and activity to defeat the enemy's physical and moral determination to fight.

II. OPERATIONAL AND ORGANIZATIONAL CONSIDERATIONS

A. INTRODUCTION

Chapter One has established a need for automated command and control capability which would provide a commander and his staff with continuous, near real time, visual display of the friendly force disposition on the AirLand battlefield. This command and control capability would automatically:

- transmit disposition data;
- receive and process disposition data into a usable format;
- correlate disposition information with other types of information in a C2 database;
- present this correlated information on a C2 display;
- disseminate this information, as required, to other headquarters and battlefield functional areas within the Army Tactical Command and Control System (ATCCS).

Chapter Two will outline the operational characteristics which must be embedded in this C2 capability to realize its full potential. It will introduce a system concept that will answer the following questions:

- Which elements will comprise the system?
- What architecture will join these elements?
- How will the disposition data be generated?
- How will the various users of this information receive it?
- How will the information be displayed?
- At what level will the data be generated, received, processed into information, transmitted, and/or displayed?

This chapter will also address the operational and organizational considerations for the proposed system. These considerations along with the need statement and threat summary of Chapter One formed a basis for the Operation and Organization Plan at Appendix A.

B. OPERATIONAL CHARACTERISTICS

The operational characteristics of any military system are those characteristics or traits which describe the system's capabilities. This section will address six major categories of operational characteristics and their corresponding traits. These categories are

aggregate in nature and representative of the traits system designers must incorporate into future C2 systems. The six categories of operational characteristics are as follows:

- General,
- Interoperability,
- Deployability,
- Survivability,
- Sustainability,
- User Interface.

1. General Characteristics

General characteristics refer to characteristics of the system that do not fit concisely under any of the other categories. These characteristics are important because they reinforce the other characteristics and provide the system with a quality of robustness, compatibility, and flexibility.

a. A Stand Alone System

A C2 system should be a stand alone, independently operating system whose capability does not depend on the interaction of many other systems. The number of participating systems required to make the overall C2 system function should be minimized.

b. Global Coverage

A C2 system must support a force with a global mission. Therefore the system must not be limited by an inability to operate in certain geographic regions or climates. The system and all of its components must be capable of providing effective and efficient support to any force, anywhere, and anytime it is needed.

c. Essential Information

A C2 system as a minimum, should provide the commander and his staff accurate, near real time information on an element's location, mission, combat posture, and operational readiness. This information must be presented in a clear and concise manner. Location information should be provided in Universal Transverse Mercator (UTM) or Universal Polar Stereographic (UPS) coordinates for the Military Grid Reference System [Ref. 20:p. 1.5]. The system should provide location accuracy with 100 meter circular error probability (CEP) [Ref. 17].

2. Interoperability

Interoperability is defined as, "...the ability of systems, units or forces to provide services to and accept services from other services, units or forces and to use the services so exchanged to enable them to operate effectively together." [Ref. 1:p. 192].

a. Joint and Combined Operations

Interoperability is an important consideration for any military system but more so for a C2 system. The U.S. Army will not fight future conflicts in isolation but, "...must be prepared to fight as part of a larger force, for example as a deployed force in NATO Europe, a combined force in Korea, or as a force tailored to meet a range of contingencies in the Middle East, Asia, Africa, or Latin America." [Ref. 15:p. 1551]. The Army's C2 systems must be capable of interoperating with our allies' C2 systems and the C2 systems of the U.S. Navy, Marines, and Air Force. Interoperability is an essential characteristic a C2 system must possess if a commander hopes to attain synchronization of forces in a joint or combined operation.

The ability to exchange information must be direct, not a convoluted, multi-interfaced exchange that requires excessive amounts of data manipulation and reformatting. The system should exchange standard data elements, organized into standard formats, with allied forces and the other U.S. services. The system should also be capable of exchanging information with other battlefield functional area C2 systems within the Army Tactical Command and Control System. [Ref. 14:p. 2]

b. Economical Concerns

All too often the U.S. designers of a new system stress the use of the most advanced technologies and give little thought to the monetary costs involved in developing, fielding, and maintaining such systems. To enhance interoperability and the acceptance of new systems by our allies, these system designers must consider our allies' ability to afford advanced technologies.

AirLand Battle 2000, an extension of the Army's current AirLand Battle doctrine into the 21st century and the predecessor of AirLand Battle Future, placed great emphasis on the development and application of new forms of technology but it, "...was not well received by the allied defense ministries. Both privately and publicly a number of them criticized development of futuristic systems it (defense ministries) envisages as being unrealistic, far too costly, and a means of fostering 'made in (the) USA' high technology equipment, which may or may not work, onto unwilling European taxpayers." [Ref. 15:p. 1551].

In view of this, future C2 systems should employ mature, state of the art technology which is economical from the standpoint of acquisition, operation, and maintenance. The monetary cost of a system and the ability of prospective users (our allies) to procure and sustain the system must be considered during system design.

c. *Information Security*

All future C2 systems must interoperate with other automated systems in the joint and combined arena in compliance with the United States Message Text Format (MTF) Programs and Standard NATO Agreements (STANAGs). The C2 system must receive, store, retrieve, transmit, and print data ranging in classification from UNCLASSIFIED through SECRET without manual encryption. The C2 system must employ measures for ensuring that information exchanged is safeguarded against exploitation by unauthorized individuals. [Ref. 14:p. 3]

3. Deployability

Deployability is defined in a strategic sense as, "...the relocation of forces (equipment) to desired areas of operation." [Ref. 1:p. 111]. Deployability can also be described as a force's or system's capability of being deployed or relocated from one area of operation to another. This definition requires a system designer to consider the system's characteristics of transportability, mobility, and initialization.

a. *Transportability*

As previously stated, "...U.S. forces must be prepared to fight....as a deployed force....(they) must retain strategic mobility. The forces (and their supporting systems) must be deployable." [Ref. 15:p. 1551]. If the U.S. Army must be prepared to conduct operations in distant lands, its C2 systems must be capable of accompanying the force to those lands. The system must be air, sea, and ground transportable [Ref. 14:p. 3]. To support rapid deployment, the system must be capable of roll on, roll off transport on a variety of cargo aircraft (USAF C-130, C-141, and C-5A). In addition, the system should be air transportable by helicopter.

b. *Mobility*

A C2 system must be as mobile as the force it supports; it must enhance, not impede a commander's ability to exercise command from any vantage point on the battlefield. A system's mobility has an influence on its ability to support continuous operations. A system that can function while moving will improve continuity of operations for a force fighting on the fluid AirLand battlefield. [Refs. 14:p. 8;21:p B.4]

c. *Initialization*

A C2 system is only useful to the extent that it can be used. In essence, the fact that a system can be deployed is of little benefit if the system cannot function without extensive preparation or set up. The system must be capable of assuming an operational posture immediately upon entering a theater of operations and must not require special ancillary equipment or extensive site preparation. The system must be capable of supporting all contingency operations regardless of the location, natural environment, or the intensity of the conflict.

4. Survivability

Survival is defined as, "...living or continuing longer than another person or thing; the continuation of life or existence...." [Ref. 22:p. 1174]. Given this definition, one can then define survivability as a person's or thing's ability to continue to live or function despite another person's or thing's efforts to terminate the first's life or ability to function.

In the context of a C2 system operating on the AirLand battlefield, survivability means being capable of operating across the wide spectrum of possible conflicts. The systems must be just as capable of providing support to a commander and his staff in a high intensity conflict, where rapid, continuous, lethal operations, electronic warfare and nuclear, biological and chemical operations are the norm as it is in a low intensity conflict where actual contact may be sporadic or intermittent.

To achieve survivability, the C2 system designer must consider the system's signature, the concept of critical nodes, the need for redundancy, electronic counter-counter measures, and operations in nuclear, biological, and chemical environments.

a. *Signature*

If a system has a signature, be it electromagnetic, thermal, or visual, it can be detected. If the system has a unique signature, it can not only be detected but it can be identified and the likelihood of it being targeted for attack increases. An ideal C2 system would be one that is totally passive; one that has no signature at all. Technology cannot provide an ideal C2 system but a more attainable goal would be to acquire a C2 system that has a slight or minimal signature which is difficult to detect and similar to others on the battlefield. A trait such as this will enhance the system's survivability.

b. *Critical Nodes*

A C2 system must be robust, it must not rely on a critical node or have an Achilles' heel embedded in its architecture. A critical node is, "...an element, position,

or communications entity whose disruption or destruction immediately degrades (or negates) the ability of a force to (provide) command and control or effectively conduct combat operations." [Ref. 1:p. 97]. A system that has or relies on a critical node is only as survivable as that critical node. If that node is destroyed or rendered ineffective, so is the system that relies on it.

c. Redundancy

Redundancy is the intentional use of excess means or ways for accomplishing the same task [Ref. 22:p. 969]. In a C2 system, redundancy is the capability to perform a task through a variety of means or alternative procedures. It is a trait that will enable a C2 system to continue to operate with no or insignificant loss of effectiveness even though the system has lost components. A C2 system that has redundancy embedded in it is characterized as being robust or strong in nature.

If a system that is redundant sustains significant losses and its ability to provide effective support is impaired, the system should degrade gracefully. This means that the system will continue to operate but with gradually decreasing efficiency. This characteristic might require the acquisition of duplicate sets of equipment or could be embedded in the system's software so that it automatically identifies and circumvents problem areas. This characteristic can only exist if there are no critical nodes in the system's architecture.

d. Electronic Counter-countermeasures

Electronic counter-countermeasures (ECCM) are, "...actions taken to ensure friendly effective use of the electromagnetic spectrum despite the enemy's use of electronic warfare." [Ref. 1:p. 127]. Forms of ECCM include the use of electronic encryption devices, employing a technology that is jam resistant, changing operating procedures, etc.

A system may be rendered jam resistant by employing various modulation techniques or by using a technology that would make the monetary or political costs associated with jamming far exceed the benefits. An example of this would be to operate the C2 system on a frequency that is used by other international users where, under normal circumstances, the C2 system would be compatible with the international users. If a belligerent nation were to attempt to jam the C2 system, it would then face the consequences, both political and operational, of that action.

The system must be protected against spoofing or unauthorized access by the enemy. The incorporation of electronic encryption devices or technologies such as frequency hopping or spread spectrum modulation, are alternatives to be considered.

e. Nuclear, Biological, and Chemical Resistance

The hardware and software components of a C2 system must be capable of supporting operations in an environment which has been contaminated with nuclear fallout or biological and chemical agents. The components of the system must not be affected by decontamination agents that will be used after a NBC attack. These traits must apply to equipment which is built to military specifications (MILSPEC) and that which is procured as nondevelopmental items (NDI). [Ref. 14:p. 3]

Components which are essential to mission accomplishment will be designated as MILSPEC items. Given this fact, these items must be shielded to survive the electromagnetic pulse of a nuclear blast. [Ref. 14:p. 3]

5. Sustainability

Sustainability is defined as, "...the ability to maintain the necessary level and duration of combat activity....it is a function of providing and maintaining those levels of force, materiels, and consumables necessary to support a military effort." [Ref. 1:p. 353]. For the purposes of this discussion, sustainability shall refer to the characteristics of obtainability, reliability, maintainability , compatibility, personnel, and training.

a. Obtainability

To ensure the benefits of a C2 system are realized as soon as possible, the system designer should attempt to use mature, state of the art technology which is available today, will not require extensive developmental or production lead time, and can be applied to the concept at hand with minor or no modification. The technology must be affordable to the greatest number of potential users.

The system should limit the amount of equipment which must be built to MILSPECs and should attempt to use fully developed, off the shelf MILSPEC government furnished equipment (GFE) where possible. The application of NDI equipment will expedite system fielding and will transfer much of the research and developmental costs to the civilian sector. A risk assessment would identify areas where NDI is appropriate.

b. Reliability

Reliability is defined as, "...the ability of an item to perform a required function under stated conditions for a specified time." [Ref. 1:p. 309]. Reliability is usually expressed as mean time between failures (MTBF) in hours. The appropriate MTBF time for a C2 system is beyond the scope of this thesis but the system must be capable of supporting 24 hour, continuous operations, in a hostile environment, and in all three climatic zones as defined by AR 70-38. [Ref. 14:p. 3]

c. Maintainability

The system should be of modular design and should make extensive use of built-in test equipment (BITE) to isolate a fault in a major component, circuit card, or module. Once a fault is isolated, the operator would remove the defective item and replace it with a serviceable item from the unit's prescribed load list (PLL). Defective items would then be evacuated through the maintenance system for repair or disposal. This capability will allow the operator to perform all operator and organizational maintenance and would not require an increase in the number of maintenance personnel necessary to support the system. [Ref. 14:p. 9]

d. Compatibility

The C2 system should have the same requirements for electrical power as the other elements which comprise the ATCCS. For example, if the system is mounted in a vehicle then it should function using the vehicle's 28 volt direct current (DC) power source. If the system is NDI equipment that would be ground mounted and is not intended for mobile operation, its power requirements should be 115/208 volts alternating current (AC), 50/60 hertz, which would be supplied by a generator or commercial power sources. [Ref. 14:p. 8]

The number of versions or variants of any system which are fielded should be limited. In addition, all versions should consist of the same component parts, with the same capabilities and the same installation or mounting configuration. Commonality of component parts will greatly reduce the burden placed on the logistics system and will greatly enhance the system's overall robustness and operational readiness rate.

e. Personnel

An automated C2 capability should be integrated into existing C2 facilities without generating the need for additional personnel. If the capability is truly automated, its operation should be transparent to its users and it should free personnel to perform other functions. This capability should be an integrated part of the ATCCS and

should use ATCCS common hardware and software. Individuals identified to operate and maintain the ATCCS equipment would assume those duties for this system.

f. Training

The training for a C2 system and any other system, will have to be planned and integrated in a coordinated effort with all the BFA systems. A capstone training plan will have to be developed as will a new equipment training plan to support fielding. Tutorials will be embedded in the system software and appropriate operator and maintenance manuals will be required. The addition of a new C2 system should have minimal impact on the overall training system. [Ref. 23:p. 6]

6. User Interface

User interface addresses how the operators will interact with the system components. Considerations for user interface are transparency, operator interface, tutorials, human factors engineering/safety, graphics and symbology, and operation under mission oriented protective posture (MOPP) conditions.

a. Transparency

A C2 system should be automated and the system should function automatically. It should transmit, receive, process, display, and disseminate information without any interaction with an operator. In essence, the C2 system's functions are totally transparent to the operator or user.

b. Operator Interface

The system should provide the operator or user a means of manipulating the system's capabilities, e.g.: a means of altering the resolution of its display, to query its database, to manually enter data or extract data from its database, to perform staff planning functions, etc. This interface may take the form of a keyboard, a mouse and icon system, or a voice actuated system. [Ref. 23:p. 3]

c. Operator Tutorials

A C2 system should be designed to be extremely user friendly and should have tutorials and on-line help programs embedded in its software. The tutorials should be designed with critical task training problem situations and exercises which approximate those expected to be encountered in actual tactical operations. [Ref. 23:p. 6]

d. Human Factors Engineering/Safety

The C2 system should be designed to facilitate safe, efficient, and effective operation and maintenance by soldiers in the fifth to ninety-fifth percentile while wearing climate appropriate clothing or equipment under tactical conditions. [Ref. 23:p. 6]

e. Graphics and Symbology

A C2 system should have the capability to generate, display, and manipulate decision graphics and standard military symbology as specified in FM 101-5-1, OPERATIONAL TERMS AND SYMBOLS [Ref. 24]. The symbology depicted on a display should automatically change as new information is received and the database is updated. [Ref. 14:p. 3]

f. Operation Under MOPP Conditions

A C2 system must be designed to allow for efficient operation by a soldier who is dressed in full NBC environmental protective clothing and equipment (mission oriented protective posture level four, MOPP 4). [Ref. 23:p. 6]

g. Army Tactical Command and Control System (ATCCS) Interface

The C2 system should interface with the ATCCS and should incorporate ATCCS common hardware and software into its design. The C2 system which will be discussed later in this chapter does employ ATCCS common hardware and software and through this process many of the previous characteristics are satisfied. In addition, through this interface, the C2 system will have access to and interface with the following systems:

(1) A Tactical Computer System. This system will provide the C2 system access to a database system for data storage and retrieval and will provide central control functions to the system data storage and display devices.

(2) A Large Screen Operation Display (LSOD). The LSOD will provide a capability for displaying all symbols, decision graphics, and selected information from the database that will be required to provide an accurate, near real time representation of the battlefield.

(3) A Tactical Computer Terminal. This system will provide the C2 system with an operator interface device for manipulation of the system's capabilities. The operator will be able to input or remove data from the system's database or issue commands to the LSOD.

The three previously identified systems are meant to be generic in nature and their names are not meant to tie or link this concept to any one C2 system which is currently being developed. The author's intent is to state a need for a system or device that provides the specified capabilities.

h. ATCCS Communications Network Interface

The C2 system will interface with the Army's Tactical Command and Control System to ensure the activities of the battlefield functional areas (BFA) are synchronized. The ATCCS interface will provide the C2 system with access to the three communication systems which support the Army in combat operations. These communication systems will allow for dissemination of the information generated by the C2 system.

i. Equipment: Military Specifications vs. Nondevelopmental Items

The C2 system will require equipment that meets full military specifications (MILSPEC) if the equipment is expected to be operated while in a man portable configuration or mounted in moving armored or wheeled vehicles or aircraft which are normally found in an Army of Excellence Division. Nondevelopmental items should be capable of supporting operations in a stationary, semi-static command post. NDI equipment should be ruggedized to allow for transport as cargo in wheeled and tracked vehicles. [Ref. 14:p. 3]

j. Line of Sight Requirements

The C2 system should minimize its need for line of sight between active elements of the system. If line of sight is required, the system should have a retransmission capability.

k. Continuous Operations

The system should be capable of supporting 24 hour a day operations and should be configured for both static and mobile operations. It should require minimal operational or organizational maintenance. [Ref. 14:p. 3]

l. Support Staff Operations

With timely and accurate information, access to a database system, a large screen operations display which can be manipulated, and access to the ATCCS communication networks, a commander's staff will have a greater ability to react quickly to changes in current operations, plan future operations, analyze alternative courses of action, and assess the impact of future decisions. [Ref. 14:p. 3]

C. THE SYSTEM CONCEPT

This section will describe a C2 system concept that will satisfy the need described in Chapter One. The description of this system will be written in broad and general terms and it will attempt to incorporate as many of the previously outlined characteristics as possible while not attempting to link the concept to a specific technology.

1. A Command and Control Support System

The system's mission or purpose is to provide commanders and their staffs, the operators, with near real time information on the friendly units located within their area of operations. Once the operators have this information they can display it along with other information (e.g., the perceived enemy situation, barrier plans, etc.) to enhance command and control of the forces in their area.

This C2 system concept will provide near real time information and will be be an enhancement to ATCCS; not a new system which is replacing an old system, but the addition of a new system element to an existing system (ATCCS) in order to satisfy a critical need.

To define this near real time information system (NRTIS) one must identify its participants or components. A superficial examination of the concept finds the system to be composed of two major components:

- a command and control node, which consists of the operators or users of information such as the commander and his staff;
- a maneuver element, which consists of units or platforms conducting operations in proximity to the command and control node.

Figure 9 illustrates the interactive relationship which exists between these two components. The actual interaction consists of the passing of data from the maneuver element to the C2 node and then the return of that data as processed information from the C2 node to the maneuver element. The data transmitted by the maneuver element would provide the C2 node a means of determining the maneuver element's identification, location, mission, combat posture, and operational readiness. This interaction would normally be an automatic function with the maneuver element periodically transmitting the required raw data to any C2 node that is capable of receiving it. The C2 node would normally be a passive participant in this process and would only transmit processed data back to a maneuver element upon request. This transmission would be sent via the ATCCS communications network.

2. The Near Real Time Information System Components

The NRTIS components (the maneuver element and the C2 node) consist of various pieces of equipment which are grouped into modules. Where possible, the components will have common or like modules and the hardware or software incorporated into these modules will be interchangeable. This commonality will add a significant level of robustness to the system and would enhance its availability, maintainability, and versatility by reducing the burden it would place on the logistic and

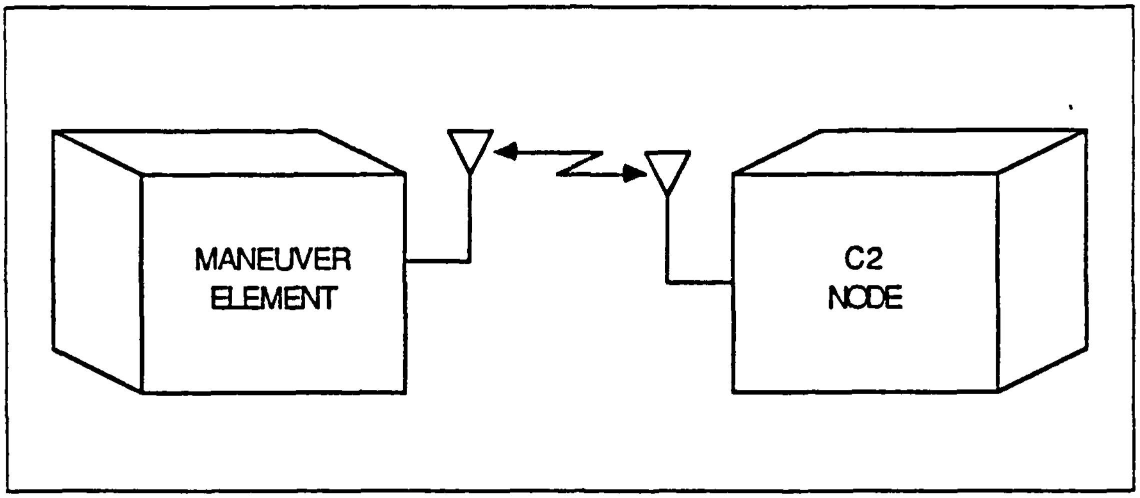

Figure 9. The Near Real Time Information System

support systems. In addition, it would allow a commander to freely move about the battlefield and command his force from any C2 node or vantage point.

a. The Maneuver Element

For the purposes of this discussion a maneuver element will be defined as, a unit (crew, squad, platoon, company, etc.) or an individual piece of equipment or platform (helicopter, tank, ambulance, etc.) whose operational characteristics dictate a need for its headquarter's C2 system to be supported by an automated near real time information system. The designation of specific units or platforms as maneuver elements will vary between battlefield functional areas. The criteria for and the designation of specific units or platforms as maneuver elements will be examined later in this chapter.

A maneuver element will normally consist of three modules:

- an antenna module,
- a limited operator interface module,
- a transceiver module.

Regardless of the type of unit or platform designated as a maneuver element, all of the modules and the components which form the modules will be interchangeable. The ability to move a set of maneuver element modules from one tank to another or to an ambulance or to a helicopter would greatly improve the system's overall availability. Commonality amongst the hardware and software must be stressed to en-

sure the system's versatility and flexibility is maximized. Figure 10 illustrates the group of modules which will form a maneuver element.

b. The Command and Control Node

The C2 node will normally be located in a command post where a commander and his staff, the operators, will have maximum access to its information and capabilities. A command post is defined as, "...a unit's or subunit's headquarters where the commander and the staff perform their activities." [Ref. 1:p. 78]. Because a command post may be established in a variety of configurations (man portable, in fixed structures, portable structures or vehicles) the C2 node must be capable of supporting a variety of operational configurations. In addition, command posts exist throughout all echelons of command but not all command posts will require a near real time information system. Therefore, not all command posts will receive a C2 node equipment set. For the purposes of this discussion, only those command posts within a BFA that are considered to be focal points of command activity, where near real time information is required, will be designated as C2 nodes. The criteria to designate a command post as a C2 node will be addressed later in this chapter. Under the NRTIS concept the C2 node will perform two main functions:

- it will receive and, through NRTIS software, process maneuver element data into information;
- it will make this information available for use by the C2 node's operators via the ATCCS common hardware and software and other users via the ATCCS communications network.

To perform these functions the C2 node has been partitioned into two separate elements which will be designated as the NRTIS element and the ATCCS element. Figure 11 illustrates this partitioning and the unilateral relationship which exists between the two elements.

The NRTIS element receives data from a maneuver element, processes this data into information and passes the information to the ATCCS element. The ATCCS element will make this information available to operators in the C2 node and will be capable of disseminating the information to other command posts.

(1) The NRTIS Element. The NRTIS element will consist of five modules:

- an antenna module,
- a limited operator interface module,
- a transceiver module,

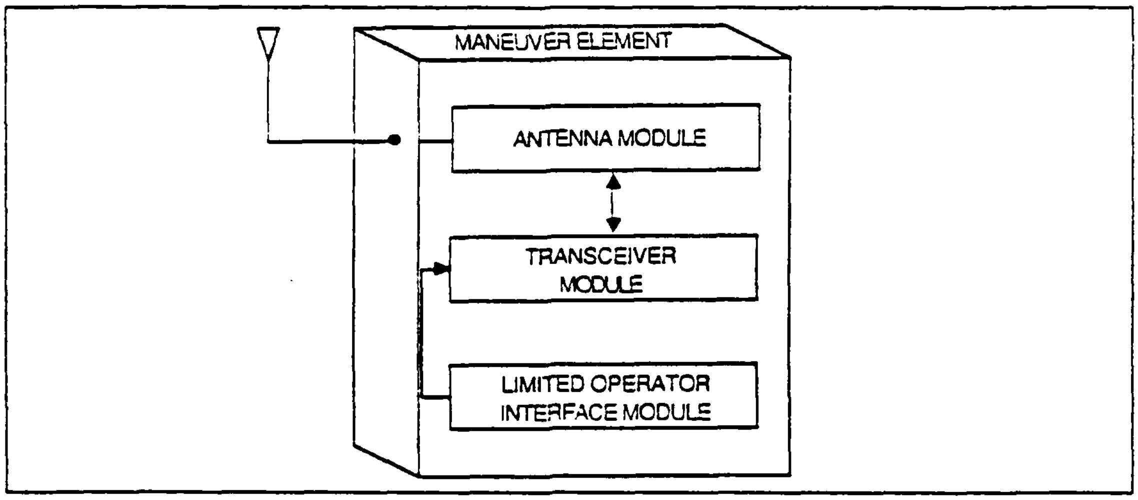

Figure 10. Maneuver Element in Modular Configuration

- a NRTIS processor module,
- an ATCCS interface module.

Each C2 node will be capable of generating data on itself in the same manner as a maneuver element does. This capability will allow other C2 nodes to determine the identification, location, mission, combat posture, and operational status of adjacent headquarters. The rate of the C2 node's transmission would be restricted to enhance its passive nature.

Each NRTIS element, regardless of the echelon or type of command post it supports, will have identical capabilities and will be comprised of similar modules and components which will be interchangeable. In addition, the NRTIS element modules which are common with the modules found in a maneuver element will also be interchangeable. Figure 12 provides an illustration of a NRTIS element in modular form.

(2) The Army Tactical Command and Control Element. The ATCCS element is the portion of the C2 node which uses the processed information that is generated by a maneuver element. It actually allows four functions to be performed:

- it allows the information to be presented in both graphic and text format;
- it provides for storage of the information;
- it provides a means of disseminating the information to other users;
- it provides a means of manipulating the information to support staff functions.

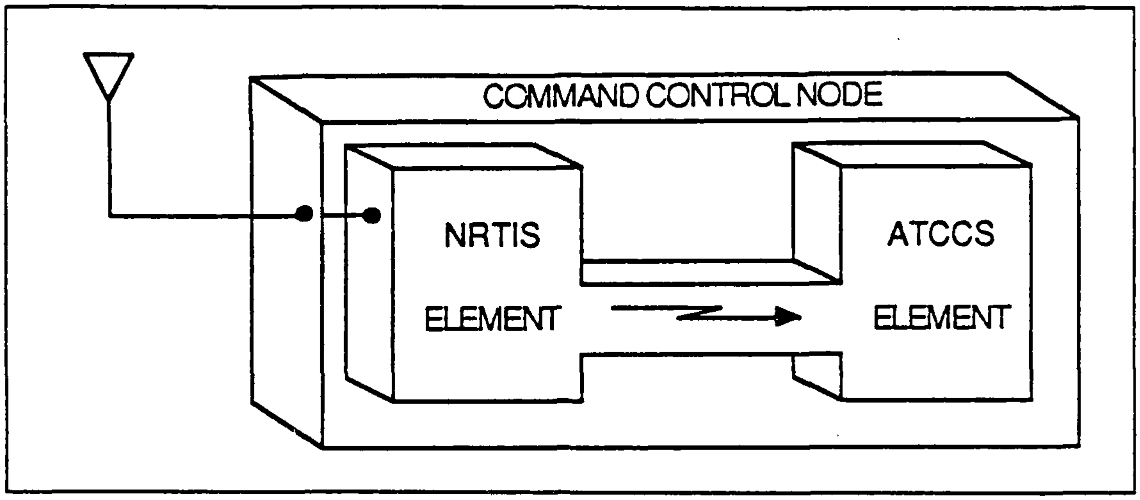

Figure 11. The Command and Control Node Elements

The modules which comprise the ATCCS element are:

- a NRTIS element interface module,
- a large screen operational display module,
- a database module,
- an operator interface module,
- a communication interface module.

This element along with the entire NRTIS concept will be an integrated part of the Army's effort to apply automation to the command and control process. These modules would use common ATCCS hardware and software thereby ensuring commonality of module capabilities and physical configurations. Figure 13 illustrates the ATCCS element in its modular configuration.

D. THE NRTIS COMPONENT FUNCTIONS

The System Concept section divided the NRTIS into its basic modules. This section will provide a concept of operation for the NRTIS concept and explain the functions and characteristics of each module.

1. Concept of Operation

To the maximum extent possible, the operation of the NRTIS will be transparent to the operators at the maneuver element and the C2 node. This will be accomplished by embedding an algorithm in the software or employing a technology which automatically causes the transceivers to periodically transmit the required data which

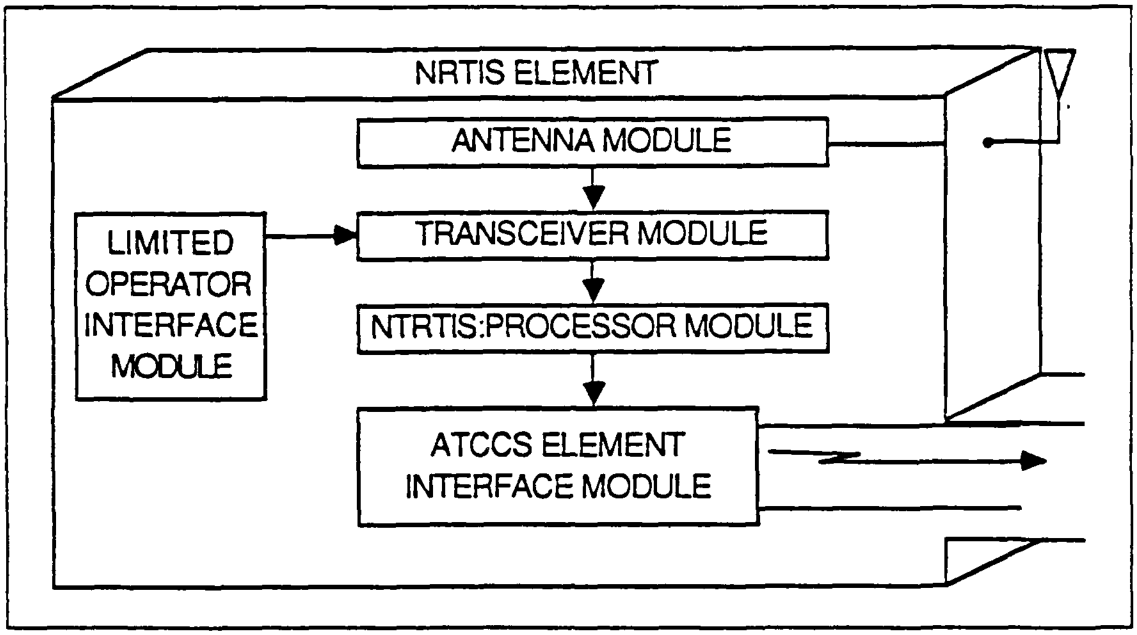

Figure 12. The NRTIS Element in Modular Configuration

will enables a C2 node to determine the maneuver element's identification, position, mission, combat posture, and operational status. (The rate of transmissions will be explored later in this chapter.)

To make this function as transparent as possible to the maneuver element's crew, certain elements of this information would have to be entered into the system prior to operation. For example, the maneuver element's identification, its mission, its combat posture, and its operational readiness would be put into the system through its limited operator interface module. Combat posture and operational readiness might change during the course of a mission and this would require that either the system automatically or the operator manually, through the limited operator interface module (LOIM), change the transmission data. The maneuver element's position will change often while conducting a mission which requires it to move. To accommodate this, a technology and corresponding software must be used to allow a C2 node to accurately determine the maneuver element's location. If a maneuver element enters a change in one of its information types, the system should immediately transmit that data to ensure the C2 node has the most timely and accurate information available. A hierarchy or control mechanism would be embedded in the system to manage this characteristic and ensure the maneuver element was not continuously transmitting.

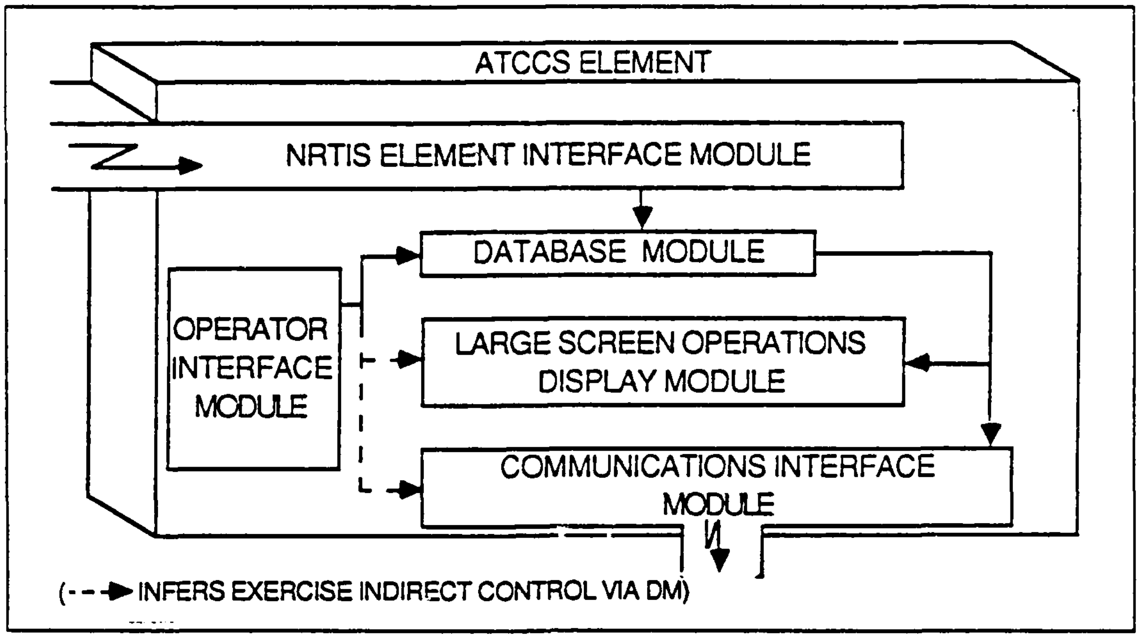

Figure 13. The ATCCS Element in Modular Configuration

The C2 node's NRTIS element will automatically receive the maneuver element's transmission, process it and pass it to the ATCCS element. The ATCCS element will automatically update the database and would pass the information to the large screen operations display module (LSOD) for display. These functions would all occur without operator interface. The database would be continuously updated as transmissions are received. The LSOD would be updated at a slower rate to ensure its operator/viewer would have time to digest and comprehend the information being displayed before it is changed. Rates of update will be discussed further, later in this chapter.

2. The Maneuver Element

As previously discussed under this concept, the maneuver element is a platform or unit whose activities a commander or staff wishes to monitor closely. The maneuver element is the data generator in the NRTIS concept but it is important to realize that data generation is not its primary mission. A maneuver element exists to accomplish a combat or tactical mission and the generation of data for the NRTIS concept is a secondary function which may help it accomplish its primary mission. In view of this, the functions a maneuver element performs under the NRTIS concept should in no way inhibit or impair its ability to accomplish its primary combat or tactical mission. The

paragraphs which follow will describe the function of each maneuver element module and a general concept of how the overall element will operate.

a. The Antenna Module

The antenna module will allow the maneuver element to receive signals from and transmit data to C2 nodes. The module should be of common shape and design so as not to identify the maneuver element as a specific unit or platform. It should not limit the maneuver element's ability operate in its normal manner or require excessive space or power to operate. Its weight should not be excessive and installation should be accomplished by an operator without aid or use of special tools.

b. The Limited Operator Interface Module

The LOIM will provide the operator in the maneuver element the ability to enter the data that will be sent to a C2 node. This device could either be manually operated or voice actuated by the maneuver element's operator or it could be mechanically or electronically actuated by another system on the maneuver element. The LOIM should have minimal effect on the operator's or maneuver element's ability to perform its primary mission.

c. The Transceiver Module

The transceiver module will be capable of receiving signals from and transmitting data to C2 nodes. It will be the primary means of transmitting data on the maneuver element's identification, location, mission, combat posture, and operational readiness to the C2 node. It may include an interface with the communication networks which form the ATCCS communication system.

3. The Command and Control Node

The C2 node will receive the data from the maneuver element through the NRTIS element. The NRTIS element will process the data into information in a usable format for use by the ATCCS element which will present the information to its operator for: display, storage, and/or dissemination. The C2 node will also act as a maneuver element in that it will be capable of transmitting data about itself for use by other C2 nodes.

a. The Near Real Time Information System Element

(1) The Antenna Module. The antenna module will allow the C2 node to receive the data being transmitted by maneuver elements and will allow a C2 node to transmit data about itself. This module will possess the same characteristics as de-

scribed under the maneuver element and its components should be interchangeable with those found in a maneuver element.

(2) The Limited Operator Interface Module. The C2 node's LOIM will possess the same capabilities and characteristics as described for the LOIM under the maneuver element and it should be interchangeable with a maneuver element's LOIM.

(3) The Transceiver Module. The transceiver in the C2 node will be capable of performing the same functions as the transceiver found in a maneuver element but it will also be capable of receiving the signals which a maneuver element's transceiver transmits. It will possess the same characteristics as a maneuver node's transceiver and to the maximum extent possible, its components should be interchangeable with those found in a maneuver element.

(4) The Processor Module. The processor module will take the data that is received by the C2 node's transceiver, and through NRTIS software, process it to determine the desired information. It will pass this processed information to the ATCCS interface module.

(5) The ATCCS Interface Module. The ATCCS interface module will take the processed information and transform it into a format which is usable by the modules of the ATCCS element.

b. The ATCCS Element

The ATCCS element is the system through which the operators will realize the true benefit of the NRTIS concept. It will receive the processed maneuver element information from the NRTIS element and apply ATCCS common software to simultaneously update its large screen operations display (LSOD) module and its database module (DM). It will possess the capability to exchange this information through the ATCCS communications interface module and will allow for operator interface to the LSOD or the DM via an operator interface module (OIM). It is important to remember that all of the modules and software found in the ATCCS element are common ATCCS items. These ATCCS items either currently exist or are being developed to support an ATCCS subordinate system which would interface with the NRTIS.

(1) The Large Screen Operations Display Module. The LSOD module will provide a full color, graphical display of the battlefield's terrain and relief features and the control measures normally found on an operations overlay (e.g.: unit locations, boundaries, phase lines, coordination points, etc.). The LSOD, through an operator's interface module and the database, should be capable of displaying other types of over-

lays and information in conjunction with the basic operations overlay. In essence, the LSOD will be the operations map board with its various overlays being stored in the ATCCS database. The LSOD should be capable of employing all of the symbology and decision graphics found in FM 101-5-1, OPERATIONAL TERMS AND SYMBOLS [Ref. 24].

The LSOD should provide a commander and the staff a near real time 'snapshot' of the battlefield situation. A quick glance at the LSOD should tell an operator:

- Who the friendly forces in his sector are.
- What the current activity of those forces is.
- What their capabilities to continue to perform those activities are.
- What the locations of those friendly forces are.
- What their relation to perceived enemy forces in the sector are. [Ref. 25:p. 7.2].

The LSOD must be capable of providing as much information as possible but this information must be conveyed to its operators in a clear and concise manner. The portrayal or positioning of a maneuver element's symbol on the LSOD should provide the operator an approximate position. In addition, the maneuver element's symbol should allow the operator to quickly differentiate the various missions, combat postures, and states of operational readiness the maneuver element can assume. All of this information should be conveyed without having to access the database. However, the operator should be capable of obtaining more precise information by accessing the database.

Without the NRTIS, the operator would have to request and receive a countless number of voice radio situation reports (SITREPS) from maneuver elements in his locale. In addition the operator would have to analyze and post these reports to various overlays and charts. Under the NRTIS concept:

- The operator will receive reports from all maneuver elements operating in his sector, not just those which are task organized to his headquarters. This will enable an operator to ensure his plans or actions are not or do not inhibit those of adjacent maneuver elements. This ability by itself should reduce friction and the possibility of fratricide on the battlefield.

- The system's software can be designed to automatically sort and post specific time critical information to the LSOD and other information to the database. The system should also give its operators a signal that critical information has just been received.

- The system will be automatic and the information will be timely and accurate because there will be limited man-machine interface at the information generation station, the maneuver element, and as information passes through the ATCCS architecture.

(2) *The Database Module.* The database module (DM) under this concept is more than a storage device, it is also a central control unit. In the discussion which follows, this module will be required to autonomously interact with and manipulate other portions of the ATCCS. It will also act as a reservoir or storage device for various forms of information. The reader should be cognizant of this so as not to become confused when the topic of discussion shifts from storage to software.

1. Database Storage:

   - The database module's storage device will be a piece of ATCCS common hardware and will incorporate ATCCS common software. The storage device will store all of the information generated by a C2 node's operators; information supplied by other ATCCS systems; and all of the NRTIS information received by the C2 node.

   - The actual amount of memory necessary to support this concept and all of the other functions the DM will have to perform is beyond the scope of this thesis. An analysis of the memory required to support this concept is in order and should be pursued by other thesis candidates.

2. Database Module Software:

   - The software which is incorporated into the DM should be capable of automatically responding to requests for information from other headquarters. The NRTIS will receive a request, conduct a search of its database, and respond automatically without operator interface. The request and the response will use the ATCCS communication networks as its communication medium.

   - The software should also be capable of generating a request for information on maneuver elements. For example, assume a rule is embedded in the software which states that, as a minimum, every hour a maneuver node will transmit and update the DM. If an hour should pass and the DM is not updated, it will automatically transmit a query to the maneuver element requesting an update. If the query is not answered, a request for information will be sent to other C2 nodes operating in proximity to see if they have had contact with the maneuver element. The C2 node will receive and sort the responses it receives and will post and store the most current. These events should all occur without an operator interface and would use the ATCCS communication networks.

   - If the only way a parent C2 node can maintain contact with a subordinate maneuver element is through another C2 node, then the parent C2 node should be able to link the two DMs. This would be performed through the OIM and would form a retransmission system. This capability would greatly enhance the overall flexibility, redundancy and survivability of the system.

   - A final characteristic which should be embedded in the DM software is the automatic generation and transmission of periodic standard operating reports to

higher and lower echelons of command. Here again, a rule would be embedded in the software which states, "Every X number of minutes (hours, days, etc.) search the database for the X bits of information (unit locations, missions, combat posture, operational readiness status, etc.) on X elements and generate a message in the proper message text format for transmission to X headquarters via the ATCCS communication network." When these messages are received at the appropriate headquarters, the information would automatically be used to update that headquarter's database and large screen operational displays.

(3) *The Communications Interface Module.* The communications interface module (CIM) will provide the NRTIS concept the ability to interact with the ATCCS communication networks. This capability will include access to all three communication networks (the area, tactical, and digital) and will enhance the concept's ability to disseminate the information it generates. The CIM will be linked to the DM and will allow the DM to automatically exchange information with other DMs in its BFA and in other BFAs. This capability will allow the NRTIS to disseminate its information across a broad geographic area and will allow operators to generate a more accurate and timely battlefield display at all echelons of command.

The software embedded in the CIM will conduct communication network management to the extent that it will determine over which communication network a given request, message or response will be transmitted. Criteria such as: networks available at the sender's and receiver's location; prioritization of information type (SITREP, logistics, administrative, etc.); the current system load and the additional load the message will add to the system; must be considered in developing the software which will make the network determination. In addition, if the transmission is not successful on one network, the software should automatically switch to another and retransmit. This process should continue until it is successful or some limiting factor is reached. In all cases, the system should inform the operator that it has either succeeded or failed to transmit a message.

It is important to note that the interaction between the NRTIS and the ATCCS communication networks will not be continuous. A C2 node will not transmit a message every time new data is received from a maneuver element. What the previous discussion does infer is that the current process of generating periodic reports, which are normally governed by standard operating procedure, could be automated and through this automation operators would receive information which is more accurate and timely.

(4) The Operator Interface Module. The operator interface module (OIM) will allow an operator to manipulate the other modules in the ATCCS element. It will allow the operator:

- to access the database to perform input and output functions;
- to generate and transmit message traffic via the CIM;
- to manipulate the LSOD:
  - to change its resolution;
  - to apply or remove various overlays;
  - to highlight various features (e.g.: road networks, maneuver units, etc.).
- to allow staff officers to perform staff functions.

The OIM would allow the staff officer to efficiently use and apply the information generated by the NRTIS in the C2 process. It will be used as a staff tool by various staff officers and ideally, each staff section would have one for its dedicated use. The OIM will most likely be a tactical computer terminal consisting of ATCCS common hardware and incorporating ATCCS common software. Each OIM will be a self contained workstation which can access the ATCCS database, generate a small scale operations display, and have an adequate amount of memory space to allow a staff officer to execute his staff functions. In addition, the OIM would provide the staff officer an automated workstation from where he could: access all of the data in the database; manipulate the graphics depicted on the LSOD; develop and store plans; and then present those plans in briefings on the LSOD while other operators monitored the current situation on other workstations.

4. The Total System Design

Figure 14 on page 57 provides a graphic illustration of the entire NRTIS concept including the relationships and interaction which occur between the various modules and the data or information each conveys.

E. OPERATIONAL ISSUES

This section will address specific operational issues which must be resolved if the NRTIS concept is to be incorporated into the ATCCS. The issues will be addressed in a question and answer format with the answers being derived from several U.S. Army doctrinal publications.

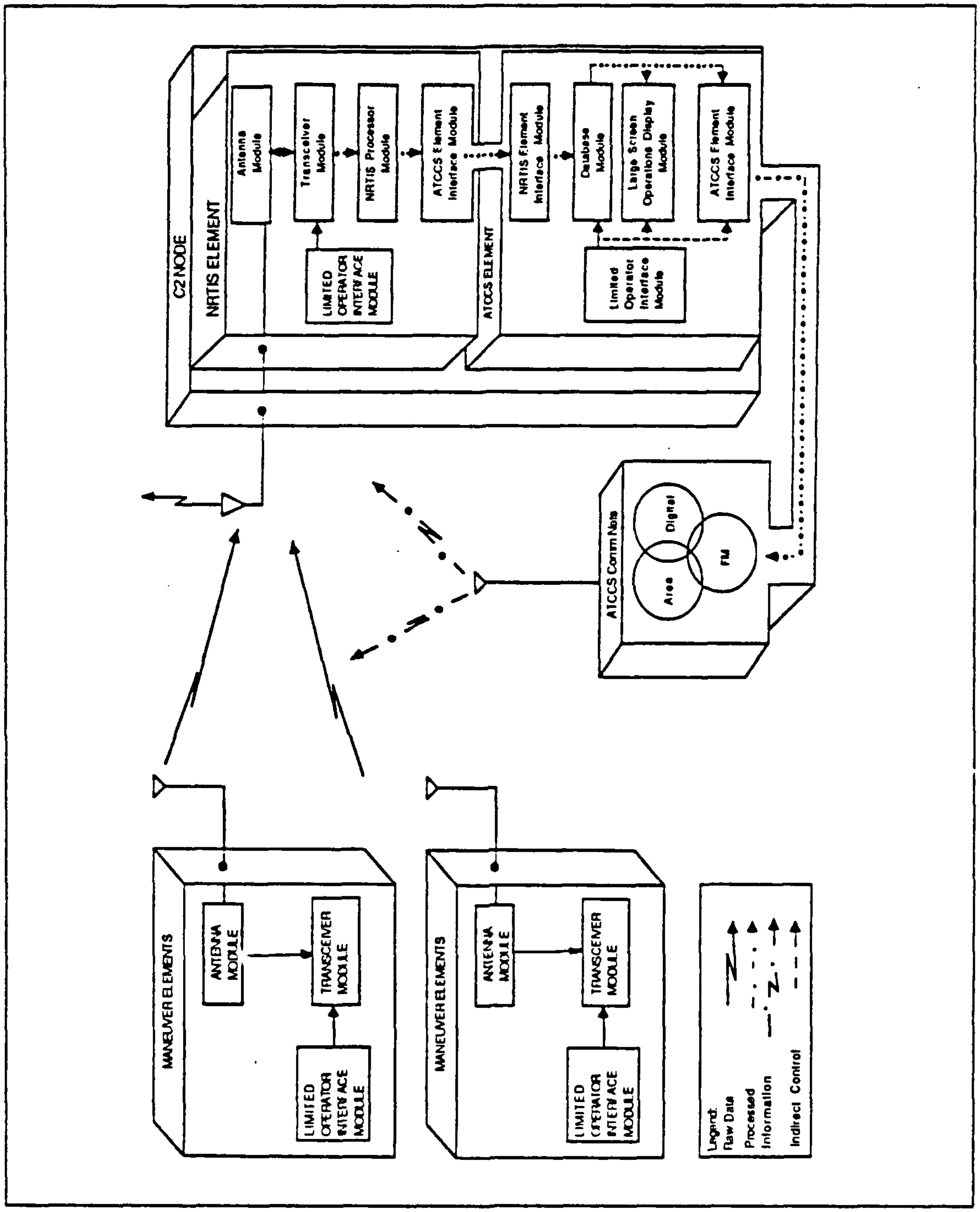

Figure 14. The NRTIS Modular Configuration

1. **What information should a maneuver element transmit?**

The maneuver element should transmit those bits of information which are essential to providing a capsulized situation report or should answer the five classical situational questions: Who, What, When, Where, and How. To do this, the maneuver element must transmit:

• its identification	Who is he?
• its mission and combat posture	What is he doing?
• its all occurring now	When was this so?
• its position	Where is he?
• its operational readiness status	How capable is he of continuing?

2. **What should the maneuver element's transmitted information convey?**

To enhance the survivability of the maneuver element, the transmission must be extremely short. Therefore, the information contained in the data must be very specific and meaningful.

a. Identification

The actual terminology or symbology presented to an operator at a C2 node must be meaningful. The level of identity must coincide with the level to which maneuver elements are designated. For example, if a squad size element is designated as a maneuver element then the system, using symbology and terminology, must convey that information to an operator. Figure 15 illustrates this point.

b. Mission

The mission a maneuver element is conducting will be determined by examining the class of operations under which the mission falls. FM 100-5, OPERATIONS [Ref. 4], divides all military operations into one of three possible classes of operations. Each class can be further divided into subclasses which characterize mission types. Table 1 on page 59 illustrates the various classes of operations and their associated missions. [Ref. 4:pp. 89-160]

All of the various missions possess unique traits which distinguish them from other missions. Yet at the same time, they all share some common traits or characteristics which can be used to describe a situation. The common situational characteristics are: movement, contact, and engagement. A maneuver element or C2 node, regardless of its mission, will either be moving or static; will be in contact with the enemy or not in contact; and will be engaged in combat with the enemy or will not be engaged.

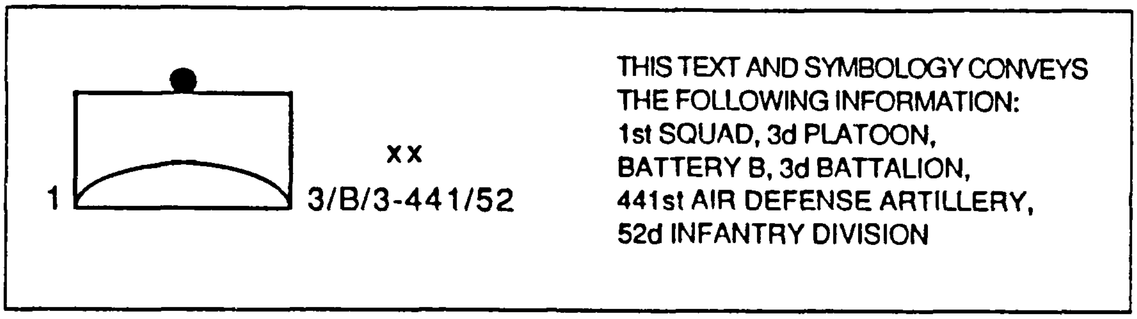

Figure 15. Maneuver Element Identity

Table 1. CLASSES OF OPERATIONS AND MISSIONS

OFFENSIVE:	DEFENSIVE:	RETROGRADE:
Attack	Area Defense	Delay
Exploit	Mobile Defense	Withdraw
Pursuit		Retire

By applying the common situational characteristics to each mission and after considering the definitions, traits, and goals of each mission as defined in [Ref. 4], it has been determined that the NRTIS must transmit situational data on four classes of operations (missions) and six situations (combat postures). The four missions which a maneuver node can conduct and the NRTIS concept must support and each mission's definition are as follows:

1. ATTACK:
   - An attack mission is defined as a maneuver element attempting to defeat the enemy by:
     - seizing the initiative and aggressively destroying the enemy's forces;
     - gaining information on the enemy and then exploiting it;
     - securing key or decisive terrain;
     - depriving the enemy of resources;
     - disrupting the enemy's attack by counterattack;
     - depriving the enemy the freedom to maneuver by taking action against the enemy.

- This mission will embody all of the offensive operations discussed in [Ref. 4] and will imply the force is moving and will continue to move once it has made contact with the enemy or engaged the enemy.

2. DEFEND:

   - A defend mission is defined as a maneuver element attempting to:
     - retain ground;
     - gain time;
     - deny the enemy access to an area;
     - damage or defeat an attacking enemy force.
   - This mission will embody all of the defensive operations outlined in [Ref. 4] and will infer the maneuver element is conducting primarily static operations or limited amounts of movement.

3. RETROGRADE:

   - A maneuver element is conducting a retrograde operation when it is attempting to:
     - gain time by slowly moving its forces rearward;
     - preserve its forces by moving them rearward;
     - avoid combat under unfavorable conditions;
     - draw the enemy into unfavorable conditions by moving friendly forces rearward.
   - This mission will encompass the terms and meanings associated with retrograde operations as found in [Ref. 4] and will assume movement is involved.

4. MOVING:

   - Moving is not an operation found in [Ref. 4] but for discussion of C2 under the NRTIS concept, it is a necessary mission type which must be recognized and defined.
   - Moving describes actions taken by a maneuver element to change its position or to conduct a noncombat related mission such as convoying. It can be related to displacement or just plain movement.
   - Movement will normally occur in territory that is controlled by friendly forces and is well to the rear of the FLOT.

c. Combat Posture

Each mission can be described by three of six combat postures. The combat posture tells a C2 node what the current situation is at the maneuver element's location. Three of the combat postures are common to the ATTACK, DEFEND, and MOVING missions. The combat postures associated with the RETROGRADE mission are different because of the unique nature of retrograde operations as defined in [Ref. 4].

The six combat postures and their definitions that will be employed to describe the situation under the NRTIS concept are as follows:

- MISSION-- ATTACK:

  1. POSTURE-- MOVING: Under this mission, this combat posture infers the maneuver node is conducting an offensive operation and is moving or maneuvering to find the enemy. The maneuver element has not sighted nor has it been engaged in combat operations with the enemy.
  2. POSTURE--CONTACT: Under this mission, this combat posture infers the maneuver element is conducting an offensive operation and is moving or maneuvering and has sighted the enemy. The maneuver element has not become engaged in combat operations with the enemy and is continuing to move to either develop the situation or to bypass the enemy.
  3. POSTURE--ENGAGED: Under this mission, this combat posture implies the maneuver element is conducting an offensive operation, has sighted the enemy, and is engaged in combat with the enemy. The maneuver element is continuing to move to either destroy the enemy, bypass the enemy, or develop the situation.

- MISSION--DEFEND:

  1. POSTURE--MOVING: Under this mission, this combat posture implies the maneuver node is conducting a defensive operation and is moving or maneuvering to assume a more advantageous position. The movement is limited and the maneuver element has not sighted the enemy nor is it engaged in combat with the enemy.
  2. POSTURE--CONTACT: Under this mission, this combat posture implies the maneuver element is conducting a defensive operation and has sighted the enemy. The maneuver element may conduct limited movement to develop the situation but it is normally assumed that it is in a static position. The maneuver element is not engaged in combat with the enemy.
  3. POSTURE--ENGAGED: Under this mission, this combat posture implies the maneuver element is conducting a defensive operation, has sighted the enemy, and is engaged in combat. The maneuver element may conduct limited movement to develop the situation or assume a more advantageous position but it is normally assumed to be in a static position.

- MISSION--MOVING:

  1. POSTURE--MOVING: Under this mission, this combat posture implies the maneuver node is moving or convoying between points which are to the friendly side of the FLOT. The maneuver element is not performing a mission which implies that enemy forces will be encountered therefore this mission is neither offensive or defensive in nature. The maneuver element has not sighted the enemy nor is it engaged in combat.
  2. POSTURE--CONTACT: Under this mission, this combat posture implies the maneuver element is moving or convoying between points on the friendly side of the FLOT. The maneuver element has sighted the enemy. The maneuver element was not and has no intention of conducting either offensive or defensive operations but it will continue to move to either bypass or avoid becoming engaged in combat. If the maneuver element intends to develop the situation and

conduct offensive or defensive operations, it would change its mission type to ATTACK or DEFEND.

3. POSTURE--ENGAGED: Under this mission, this combat posture implies the maneuver element is moving or convoying between points on the friendly side of the FLOT. The maneuver element has sighted the enemy and is engaged in combat. It is assumed the maneuver element will continue to move to bypass the enemy. If it cannot bypass the enemy, the maneuver element will change its mission type to ATTACK or DEFEND.

- MISSION--RETROGRADE:

  1. POSTURE--DELAY: Under this mission the maneuver element is moving rearward and is slowly releasing control of terrain to the enemy so as to gain time. The maneuver element is moving and is engaged in combat with the enemy and is attempting to inflict severe casualties on the enemy while simultaneously preserving freedom to maneuver.

  2. POSTURE--WITHDRAWAL: Under this mission the maneuver element is moving rearward and is in combat with the enemy. The maneuver element is voluntarily disengaging from combat in an effort to preserve its forces or to free itself to assume a new mission.

  3. POSTURE--RETIREMENT: Under this mission, the maneuver element is moving rearward and is not in active combat with the enemy. This movement is normally conducted as a tactical road march or convoy and would equate to the combat posture of moving. If a maneuver element were to come in contact or become engaged by an enemy force the maneuver element would change its posture to withdrawal.

d. Location/Position

The C2 node must know where the maneuver element is if it is to gain any meaning from the information the maneuver element generates. For maneuver nodes operating on the surface of the earth (tanks, trucks, etc.) the C2 node should receive position data which is accurate to 100 meters CEP [Ref. 17]. For aerial platforms (helicopters, remotely piloted vehicles, airplanes, etc.) the C2 node should receive surface positional data which is accurate to 100 meters CEP and altitudinal data which is accurate to 100 feet.

The functions of collection, transmission, and processing of the data necessary to determine a maneuver element's position will be embedded in the system's software. The function of using this information to generate a display will also be embedded in the NRTIS software. Transparency of system functions must be maximized at the C2 node and at the maneuver element.

e. Operational Readiness/Status

The C2 node will require information on the maneuver element's ability to accomplish its assigned tasks or to continue to perform its current operations. This information could be conveyed in three ways:

- by providing an extensive and detailed logistic report which covers all classes of supply and all authorized equipment;
- by providing a limited report that addresses only combat essential items (e.g: ammunition, fuel, combat systems, etc.);
- by providing a commander's estimate of his operational readiness which would be extremely narrow in scope (unit is: mission capable, mission capable with limitations, or not mission capable).

In the interest of being brief but concise, the NRTIS concept should require the maneuver element to transmit the following operational readiness information:

- Unit Strength: The number of major weapons systems (pacing items) which are operational.
- Supply Status: This should address only combat critical supplies such as Class III (fuel) and Class V (ammunition) which are necessary to support major weapon systems.
- Commander's Estimate: This should state the commander's subjective opinion of his force's capability of accomplishing the assigned mission (e.g.: unit is 90% mission capable; unit is 80% mission capable; etc.).

This information would be entered into the system via the LOIM and would be part of the maneuver element's periodic transmission. If the process of collecting the data on supply classes could be automated and integrated into the transmission without operator interface, the value of the NRTIS would be enhanced.

3. How often should a maneuver element transmit?

A maneuver element's periodic rate of transmission will be derived from evaluating the following criteria and applying them to each maneuver element.

a. Rate of Movement

A maneuver element's rate of movement has a direct correlation to the amount of territory it can cross in a given time period. A maneuver node which moves at a great rate will cross more territory than one that moves at a slow rate and in doing so will come in contact with more C2 nodes or unit boundaries. In view of this, a maneuver element that moves at greater rates of speed needs to have a greater rate of transmission or shorter period between transmissions than a maneuver element that moves at a slow rate of speed or which is static.

b. The Maneuver Element's Mission

The mission a maneuver element is conducting and the rate at which operations are conducted, will have an impact on the maneuver element's transmission rate. During defensive operations, where movement is limited, there may be less of a need for periodic information updates; especially if the maneuver element is in a static position and operations are moving slowly. During offensive operations or retrograde operations where there is movement and operations are occurring at greater rates, a greater transmission rate may be required to ensure an accurate assessment of the situation is possible.

c. The Enemy

The enemy the maneuver element is facing and its ability to move forces or strike, must be considered when determining the update rate or in controlling the update rate. If the enemy possesses the ability to quickly change the situation, the system must be capable of responding and providing a quick update to the C2 node.

d. Inter-Branch or Battlefield Functional Area Relationships

The relationships which exist between various branches or BFAs may generate a requirement for different transmission rates. An example is the relationship between the aviation community and the air defense community. If fratricide is to be avoided, the air defense units must know where the aviation assets are and that information must be disseminated to the dispersed air defense fire units in a timely manner. This need for rapid collection and dissemination of information may require that aerial platforms transmit at a greater rate than ground platforms to ensure the most timely and accurate information is available.

4. What information should a C2 node receive?

A C2 node, regardless of its BFA, should be capable of receiving all data signals transmitted by any maneuver element operating in proximity to it. This capability will:

- allow the C2 node to generate the most accurate and complete display of battlefield disposition;
- enhance the system's robustness and flexibility because any C2 node will be capable of supporting any echelon of command;
- allow the C2 node to act as a relay or retransmission station for other C2 nodes which cannot receive a maneuver element's signal;
- establish a large database which will allow operators to develop better and more detailed plans.

5. What information should a C2 node display?

In today's manual operations center the operations map board presents the commander and staff a basic illustration of the current situation on the battlefield. The basic map board provides a graphic display of control measures and friendly unit locations. If the integration of additional information is desired (e.g.: opposing forces, battlefield obstacles, mobility corridors, etc.) additional overlays are developed and applied to the map board. Information on a unit's operational readiness status is usually maintained on a chart or status board which is adjacent to the operations boards.

The NRTIS concept will be capable of providing the same information that the current system does but NRTIS will use a LSOD in lieu of a map board or charts. The actual information that will be displayed under the NRTIS concept will be dependent on what the C2 node's operators decide is relevant. The C2 node will be capable of directly receiving information on all maneuver element's operating in proximity to it. In addition, the C2 node will receive information on subordinate and superior maneuver elements via the ATCSS communication networks. The operators at the C2 node will have to determine what information they wish to view and using the software embedded in the system, they will tailor the LSOD to fit their needs. For example, an infantry brigade should be capable of tailoring the information that will go onto its LSOD to just those units under its task organization and all units operating on its flanks. Or it might also wish to display all helicopters conducting operations in its sector. Or it may wish to see all maneuver elements which are moving on the ground so it can assess traffic flow.

The operators will also have the capability through the OIM to enter information into the database which can also be placed on the LSOD. This capability, in conjunction with those previously addressed, will enhance the clarity and meaningfulness of the battlefield display.

6. What information will be displayed at a C2 node?

The displays must provide as much information as possible in the clearest and most concise way. The current system for determining what information should be gathered to be displayed on maps, overlays, and charts attempts to adhere to this axiom. To accomplish this, a process of echeloning is used which requires a headquarters to maintain information on elements that are two levels below it and one above. This process means that a headquarters at a certain level of command will only maintain or display information on specific echelons or levels of command. For example, a company

commander will maintain information on his platoons and squads whereas a brigade commander will maintain information on his battalions and companies.

The general rule which is applied to this practice is, "..a commander fights one level below his echelon of command but thinks (or plans for operations) two levels below his echelon." In view of this, a commander must maintain and display information on elements which are two levels below his own echelon of command. Table 2 depicts this rule as it applies today. [Ref. 12:p. 4].

Table 2. INFORMATION REQUIREMENTS BY ECHELON

ECHELON OF COMMAND:	ECHELON IT FIGHTS: (DIRECTS)	ECHELON IT THINKS: (PLANS FOR)
Division	Brigade	Battalion
Brigade	Battalion	Company
Battalion	Company	Platoon
Company	Platoon	Squad

The actual information a headquarters normally displays is the same as that which the NRTIS concept intends to provide. Ideally the NRTIS concept, through its interface with the ATCCS communication networks and the OIM's ability to apply ATCCS software the LSOD's resolution, will allow operators at higher echelons of command to have access to and display information on the lowest echelon of maneuver elements.

7. How will information be displayed?

Under the NRTIS concept the LSOD and OIM display will provide the same basic information as found in a manual operations center. Staff officers will prepare information overlays using an OIM and will store them in the database until such time as the overlays are required. When an overlay is needed, it will be called from the database through the application of ATCCS software and will be displayed on the LSOD. The NRTIS will be capable of layering many overlays on the LSOD to allow for simultaneous viewing.

The display must, at a glance, provide an accurate, near real time representation of the current battlefield. The best way to accomplish this is through the use of symbols and terms which have specific meanings and which will convey maximum information

with minimum use of graphics capabilities. The C2 node's displays will, to the maximum extent, use standard map symbols, control measures, and operational terms as found in [Ref. 24] SYMBOLS.

To display information which is stored in the database and which may or may not be combat critical or which may not be easily transformed into a symbol, an off center information block capability should be developed. This capability would allow an operator, using an OIM, to highlight a maneuver element, access the database, and present all or select bits of information on that unit off in some corner of the display screen away from the maneuver element's symbol. Information which might be displayed in an off center information block include the following:

- a maneuver element's full Combat Arms Regimental unique designation;
- a maneuver element's six digit grid coordinates;
- a maneuver element's mission;
- a maneuver element's combat posture;
- a maneuver element's detailed logistics status, as of some date-time group;
- a maneuver element's detailed personnel status, as of some date-time group;
- a maneuver element's overall operational readiness status, as of some date-time group.

The discussion of the NRTIS concept which follows provides an insight into symbology and terminology considerations which must be addressed by hardware and software developers.

a. Identification

The ability of the NRTIS concept to use symbology and terminology to provide a battlefield display which provides a maneuver element's full identity at a glance is directly related to the display module's physical size, level of pixel density, and the software's graphics capabilities. Ideally an operator should be capable of displaying any symbol found in [Ref. 24] with its appropriate unique designation as specified by the Combat Arms Regimental System (CARS) as seen in Figure 15 of this thesis. If it is determined that selected combat platforms will be designated as maneuver nodes and the full CARS designator is to be displayed, then it becomes evident that the display screen will become excessively cluttered with CARS designations. An alternative to full CARS designators must be identified. A modified or short designator or no designator for normal screen display with a full designator being displayed in an off center text block is an alternative.

b. Position/Location

To display a maneuver element's position or location, the ATCCS element's software will apply the accepted rules as follows: "...the center of mass of the symbol indicates the general vicinity of the unit. If a staff is added to identify a headquarters, the base of the staff will indicate the precise location of the headquarters." [Ref. 24:p. 2.26].

c. Mission

To designate a maneuver element's mission the basic symbology found in [Ref. 24] must be expanded. The presence or absence of an additional symbol could be used to specify what type of mission a maneuver element is conducting.

d. Combat Posture

To designate a maneuver element's combat posture the basic symbology found in [Ref. 24] must be expanded. The presence or absence of an additional symbol or a change in the symbol's color could be used to specify the maneuver element's current combat posture. A direction of movement indicator may be a beneficial attribute incorporated into combat postures that involve movement.

e. Operational Readiness/Status

To provide an 'at a glance' representation of a maneuver element's operational readiness status the system should employ a visual technique which equates percentage of field filled with operational readiness. The percentage of field fill would be illustrated by a change in the color of the symbol's field as it becomes less mission capable. The precise manner in which a maneuver element's OR status is determined is a topic for further study. Alternatives include:

- allowing the maneuver element's commander's subjective estimate to determine the maneuver element's OR status, which in turn would determine its percentage of fill;
- developing an algorithm and embedding it in the ATCCS element's software which will use all available data to derive a rating that would determine percentage of fill.

If a more detailed listing or presentation of a maneuver element's OR status is desired then an off center block should be used.

8. How often should the database and displays be updated?

Ideally the database and the displays should automatically be updated with new information as soon as it is received. This event will be a function of:

- the maneuver element's transmission rate;
- the maneuver element's rate of movement;

- the maneuver element's mission;
- the receipt of periodic situational and logistics reports;
- the receipt of responses to queries for information;
- operator input of information into the system.

If the system automatically updated itself at a continuous rate the operators might never be able to use the information. Conceptually there is an acceptable rate at which the system and the human operator can function to optimize efficiency. The determination of that rate is beyond the scope of this thesis but suffice it to say that the database should receive immediate and continuous updates and the display screens should respond immediately to changes in mission and combat posture and should provide a periodic update for location and OR status.

9. What information should a C2 node pass on to other C2 nodes?

If the receiving headquarters is within the C2 node's chain of command, it should use the ATCCS communications networks to pass the processed NRTIS information. This information could be the basic maneuver element report of identification, location, mission, combat posture, and operational readiness status or it could be more detailed, in depth reports that were compiled from additional data found in the C2 node's database. The system's software should allow the C2 node to establish a direct link to superior, subordinate and adjacent headquarters so that time sensitive or critical maneuver element information can be transmitted immediately upon receipt. The software should also allow the system to automatically and periodically transmit situational/status reports that are required by current standing operating procedures.

If the headquarters is not within the C2 node's chain of command, it would only pass information when that headquarters requested it. This exchange of information would be conducted over the ATCCS communication networks. The only information that should automatically be transmitted to another headquarters is the basic maneuver element report. Requests for other information would have to be dealt with on a need to know basis to preserve database security. If a need arose, the software should allow a C2 node to establish a link with another C2 node so that a maneuver element's basic report could automatically be relayed between them.

10. How will line of sight problems be avoided?

Line of sight is a limiting factor in almost all C2 systems that employ the electromagnetic spectrum as a communications medium. To avoid its impact on future systems, designers must do the following:

- develop or employ technologies which are not line of sight dependent;
- develop and employ technologies which can circumvent the difficulties the line of sight requirement causes (e.g., satellites, high frequency radio waves, etc.);
- develop and distribute economical and automatic retransmission devices;
- develop and integrate an automatic retransmission capability or procedures into the operator's system components.

11. Who will control the NRTIS system?

As the concept is currently conceived, there will be no single node that is the keystone or net control station. Each maneuver element and C2 node is an independent, stand alone node that does not need any other node to function.

As for management of codes, message formats, and encryption material:

- Each maneuver element should be capable of loading its unique CARS designator into the transceiver and through the software this will be encrypted to protect the maneuver element's identity.
- The system will incorporate ATCCS common message text formats.
- Over the air rekeying should be employed if it becomes necessary to use encryption devices on this system. If it is necessary to use manual key lists then normal security measures currently in effect would have to be applied to this system.

F. ORGANIZATIONAL CONSIDERATIONS

1. Introduction

This section will establish criteria to be used to determine what organizations or platforms should be designated as maneuver elements or C2 nodes. The application of the criteria to each BFA and the final determination of what units or platforms should be identified as maneuver elements or C2 nodes is an area for further study and will not be addressed in this thesis.

2. The Criteria

In order to determine what units or platforms should be designated as a maneuver or C2 node, it is necessary to establish a set of criteria which, when applied to a specific unit or platform will identify a clear and real need for the near real time information system.

The criteria were derived, by the authors, from an examination of those operational characteristics which tend to inhibit, impede, or complicate a commander's ability to exercise effective command and control. A total of six criteria were identified as being relevant. They are as follows:

1. a unit or platform's mission,

2. dispersion of units or platforms on the battlefield,
3. a unit or platform's rate of movement,
4. a unit or platform's availability,
5. a unit or platform's criticality to mission accomplishment,
6. a unit or platform's normal mode of employment.

It is important to remember that, for a given unit or platform, each of the criteria is scenario dependent. This means that careful consideration will have to be given to each when final designation of units and platforms is made.

a. Mission

Mission refers to an organization's or platform's doctrinal reason for being, as defined by that organization's capstone doctrinal publication. A mission may be classified as combat, combat support, or combat service support. For example: The mission of the Air Defense Artillery is, "...to nullify or reduce the effectiveness of attack or surveillance by hostile aircraft or missiles after they are airborne, thereby supporting the primary Army function of conducting prompt and sustained land warfare operations." [Ref. 26:p. 1.1].

- Maneuver Element: If knowing an organization's or platform's disposition enhances the controlling headquarter's ability to accomplish its mission, then that organization or platform will be designated as a maneuver element.
- C2 Node: If knowing the disposition of a maneuver element is critical to and/or would enhance mission accomplishment, then that headquarters will be designated as a C2 node.

b. Dispersion

Dispersion describes the average doctrinal distance between similar organizations or platforms or the area an organization or platform is responsible for controlling.

- Maneuver Element: If the dispersion between like organizations or platforms is more than one kilometer or if the area an organization or platform is responsible for covering exceeds 10 square kilometers, then it will be designated a maneuver element.
- C2 Node: If a headquarter's organizations or platforms are normally dispersed on the battlefield over a 20 square kilometer area then it will be designated as a C2 node.

c. *Rate of Movement*

Rate of movement describes the speed at which an organization or platform normally conducts combat operations or if it is not a combat vehicle, the speed at which it conducts normal tactical operations.

- Maneuver Element: If an organization's or platform's normal combat or tactical speed exceeds 50 kilometers per hour (KPH) then it will be designated as a maneuver element.
- C2 Node: If a headquarter's organizations or platforms normally conduct combat or tactical operations at speeds in excess of 50 KPH, that headquarters will be designated as a C2 node.

  If a headquarter's organizations or platforms may have a direct influence on other organizations or platforms which conduct normal combat or tactical operations at speeds in excess of 50 KPH, then that headquarters will be designated as a C2 node.

d. *Availability*

Availability can be described as the number of like or similar units or pieces of equipment normally found in a division which are capable of performing a given mission.

- Maneuver Node: If a maneuver element is considered to be a rare or constrained resource within a division and there are no suitable surrogates in the division which could be substituted to perform the maneuver element's mission without adversely effecting the battle outcome, then that element should be designated as a maneuver element.
- C2 Node: If a headquarters must exercise command and control over a constrained resource and there are no suitable surrogates which could be employed as substitutes for that element without having an adverse effect on battle outcome, then that headquarters should be designated as a C2 node.

e. *Criticality*

Criticality can be defined as those capabilities which are essential to ensuring victory and if control of those capabilities is lost, the outcome of any battle would become questionable.

- Maneuver Element: If a maneuver element possesses valuable capability such that its presence or lack of presence in a battle would either greatly enhance or deter a unit's ability to attain victory, then that element should be designated as maneuver element.
- C2 Node: If a headquarters is responsible for providing effective command and control over a maneuver element which possesses a valuable capability such that its presence or lack of presence in a battle would either greatly enhance or deter a unit's ability to attain victory, then that headquarters should be designated as a C2 node.

f. Mode of Employment

Mode of employment refers to how an organization or platform is normally assigned a mission or employed. Does an organization normally fight as a company size element or do they conduct operations as an autonomous platoon in support of another force?

- Maneuver Element: If an organization or platform normally conducts its operations as an autonomous force, away from its parent headquarters, then it will be designated as a maneuver element.
- C2 Node Element: If a parent headquarters must provide command and control to an organization or platforms that normally operate as autonomous elements in support of another headquarters, then the parent headquarters will be designated as a C2 node.

3. The Application of the Criteria

This section will provide an example of how the aforementioned criteria can be applied to a given organization to designate units or platforms as either maneuver elements or C2 nodes. A divisional Air Defense Artillery battalion will be the organization used in this example.

a. Maneuver Element Designation

1. MISSION: The divisional Air Defense Artillery (ADA) battalion performs a combat support mission. It is a supporting element in the combined arms team and usually has a subordinate but key role in planning operations. It is a force multiplier under the combined arms concept. Knowledge of the ADA battalion's force disposition would enhance the controlling headquarter's ability to accomplish its assigned mission. In view of this, the elements which form an ADA battalion meet the criteria for designation as maneuver elements.
2. DISPERSION: The ADA battalion will deploy its assets across the division's sector, an area that is approximately 2,209 square kilometers (47 by 47 kilometers). A battery within the battalion may be assigned the mission of supporting a forward brigade which has a sector with an area that is approximately 300 square kilometers (15 by 20 kilometers). The battery will assign its platoons and sections the mission of providing air defense protection to static assets or maneuver battalions. The platoons and sections will disperse their fire units (weapon systems) around an asset or within the maneuver battalion's sector in accordance with ADA doctrine. The doctrine for weapon system dispersion is as follows:

   - Stinger Missile System: 2-4 kilometers;
   - Vulcan Air Defense Gun: 1-1.5 kilometers;
   - Forward Area Alerting Radar (FAAR): 9 kilometers.

   The dispersion of ADA weapon systems meets the criteria established for designation of a unit or platform as a maneuver element. [Refs. 20:pp. 2-3; 27:p. 6.7; 28 :p. 4.2]

3. RATE OF MOVEMENT: The fire units within an ADA battalion do not normally operate at speeds in excess of 50 KPH. Therefore, the fire units do not meet the criteria for rate of movement.

4. AVAILABILITY: There is only one ADA battalion in an AOE division. This battalion is responsible for providing air defense protection to the entire division. A battalion, organized under the J-Series Table of Organization, consists of 75 Stinger Missile System Crews, 27 Vulcan Air Defense Guns, and 6 Forward Area Alerting Radars. These assets must provide air defense protection over the division's area which is approximately 2,209 square kilometers. This mission must be accomplished in accordance with ADA doctrine which restricts fire unit dispersal as cited above. These two points support the contention that the assets of an ADA battalion are constrained and their availability is limited. In view of this, the ADA fire units meet the criteria for designation as maneuver elements. [Refs. 29; 20:pp. 2-3]

5. CRITICALITY: The threat forces which the U.S. Army may face in a high to mid intensity conflict are capable of conducting large scale air operations. These operations pose a serious threat to Army operations. The ADA battalion in a division is the only ground asset at the divisional level that is dedicated to countering this threat. This fact classifies ADA weapon systems as critical asset who's presence or lack of presence, in a battle may determine a force's ability to accomplish its mission. In view of this, the ADA fire units meet the criteria for designation as maneuver elements. [Ref. 26:pp. 1.6-1.12]

6. MODE OF EMPLOYMENT: ADA fire units are employed as dispersed platoons or sections. They normally conduct their air defense missions as autonomous elements in support of a maneuver force. They are normally deployed away from their parent headquarters and supported headquarters. In view of this, ADA fire units meet the criteria for designation as maneuver elements. [Ref. 27:pp. 6.1-6.30]

7. SUMMARY: The weapon systems assigned to a divisional ADA battalion meet five of the six maneuver element designation criteria. An argument can be made that their limited availability and criticality to mission accomplishment, requires maximum utilization of ADA assets therefore they are never placed in reserve and will constantly be moving to assume new support missions and to enhance their survivability. This excessive amount of movement must be considered as an additional criteria that can be used as a surrogate to the rate of movement criteria thereby allowing the ADA weapon systems to meet all six criteria.

8. CONCLUSION: The weapon systems in a divisional ADA battalion should be designated as maneuver elements.

b. C2 Node Designation

1. MISSION: ADA platoons and sections are the lowest level of headquarters that conducts planning for combat operations. The weapon systems that comprise a platoon or section must autonomously execute the plans that are developed by the platoon or section headquarters. In addition, the weapon systems must operate as dispersed elements on the battlefield. To properly execute command and control over its assigned weapon systems, the ADA platoon and section headquarters must know the disposition of its weapon systems. In view of this, ADA platoon and section headquarters should be designated as C2 nodes.

The ADA battery headquarters is the focal point for air defense operations within a brigade sector as the ADA battalion headquarters is the focal point within a division. Both of these headquarters must know the disposition of their assets to effectively exercise command and control. In view of this, the ADA battery and battalion headquarters should be designated as C2 nodes.

2. DISPERSION: The dispersion of an ADA platoon will be determined by the mission, the enemy, the terrain, the troops available, and the time available. Given these considerations and ADA doctrine, it is evident that only the Vulcan platoon headquarters does not meet the criteria for designation as a C2 node. The ADA battery and battalion headquarters meet the dispersion criteria and should be designated as C2 nodes.
3. RATE OF MOVEMENT: The ADA community must interface and interact with the aviation community and the aviation community does normally conduct operations at speeds in excess of 50 KPH. In view of this, all ADA headquarters (platoon, section, battery, and battalion) meet the criteria for designation as C2 nodes.
4. AVAILABILITY: ADA weapons systems have been defined as limited or constrained assets. ADA headquarters must exercise command and control over these constrained assets for which there are no suitable surrogates. In view of this, all ADA headquarters meet the criteria for designation as C2 nodes.
5. CRITICALITY: ADA weapon systems have been defined as being critical to determining battle outcome. Their criticality has designated them as maneuver elements. ADA headquarters must exercise command and control over these critical weapon systems. In view of this, all ADA headquarters meet the criteria for designation as C2 nodes.
6. MODE OF EMPLOYMENT: ADA platoons, sections, and batteries autonomously execute air defense plans in support of other headquarter. ADA batteries must exercise command and control over platoons and sections as the battalion must over the battery. In view of this, ADA battery and battalion headquarters meet the criteria for designation as C2 nodes but the platoon and section headquarters do not.
7. SUMMARY: Only ADA battery and battalion headquarters meet all six criteria for designation as C2 nodes.
8. CONCLUSION: All divisional ADA battery and battalion headquarters should be designated as C2 nodes.

The intent of the previous example was to demonstrate how the authors, using their interpretation of doctrine, would apply the criteria to one specific functional area. It is evident that the six criteria do not provide a concise 'cookie cutter' approach to determining what organization or platform should be designated as a maneuver element or C2 node. Further study and refinement is necessary.

4. The NRTIS Architecture

The previous example can be applied to an architecture to demonstrate how the concept would function. Figure 16 illustrates the NRTIS architecture for the ADA

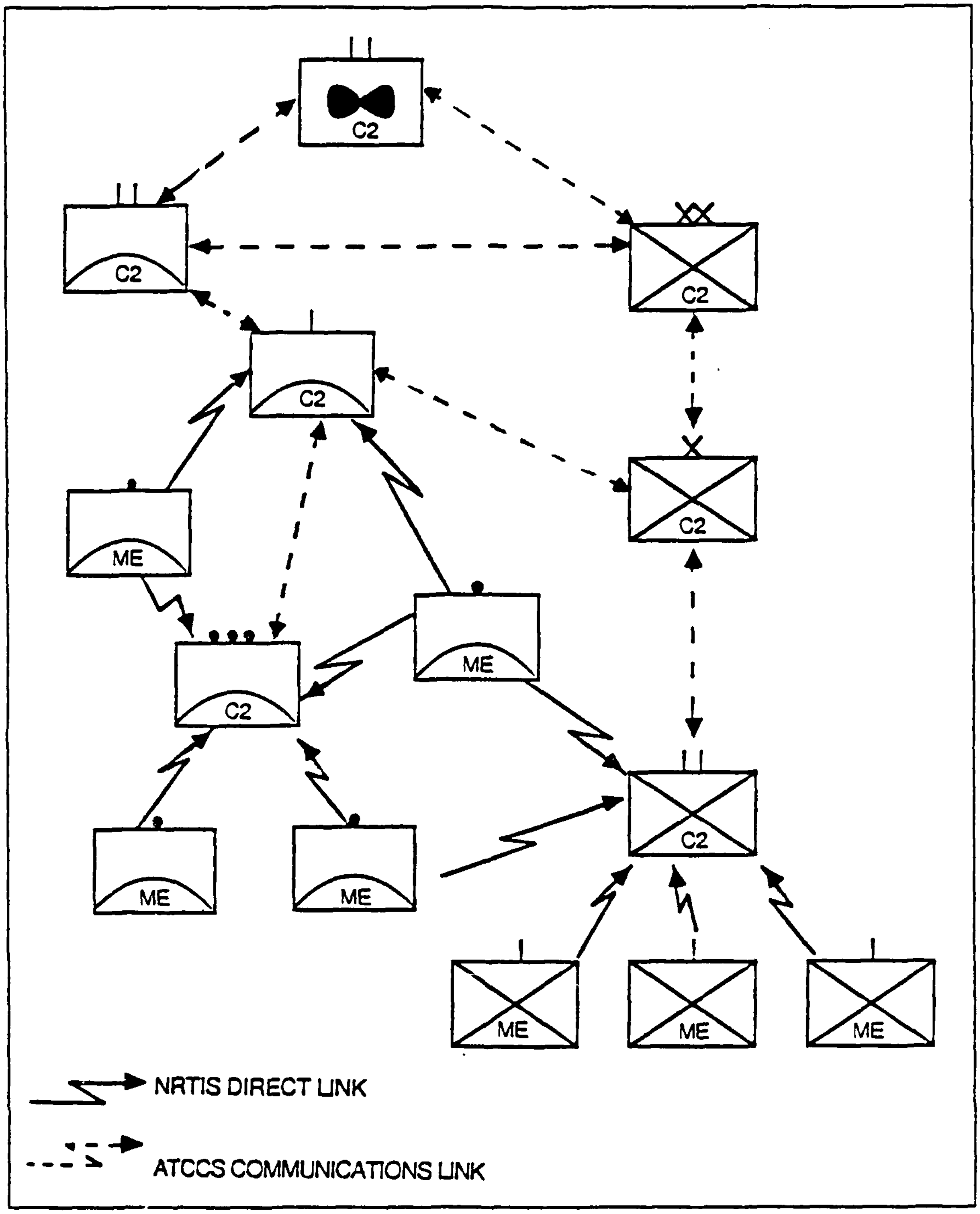

Figure 16. NRTIS Architecture

battalion cited in the previous example. The various ADA weapon systems and infantry companies are dispersed on the battlefield and are equipped as maneuver elements (ME).

The ADA platoon, battery and battalion headquarters are C2 nodes, as are the other battalion, brigade, and division headquarters depicted in the figure. Note that the NRTIS concept, through the ATCCS communication networks, ensures the supported and superior headquarters receive timely, accurate, and relevant information on the ADA weapon systems. Also note that the NRTIS allows headquarters that are not in the chain of command to receive information on the ADA weapon systems.

G. SUMMARY

This chapter has taken a need, as defined by Chapter One, and has described a concept for a C2 system which, in conjunction with other ATCCS elements, will satisfy the need. This chapter's description has identified the operational characteristics and operational and organizational considerations which are applicable to a C2 system. In Chapter Three of this thesis technology will be applied to this concept and a feasible solution to the defined need will be identified.

III. A PROPOSED TECHNICAL SOLUTION

A. INTRODUCTION

1. Purpose

The purpose of this chapter is to investigate a proposed technical solution to an identified command and control deficiency. Specifically, the concept outlined in "An OMEGA/Transponder Display System" by Litchford and Saganowich will be examined in terms of its ability to generate and display friendly combat forces identification, relative position, and a variety of combat related information. [Ref. 30]

The technologies involved are part of three mature, operationally certified systems, each supporting large user communities consisting of civil and military subscribers. This assessment will look at the proposed integration of these technologies and this system's relative merit.

2. Objectives

The objectives of this examination are:

- determine if this concept can provide a near term solution to a critical command and control deficiency;
- establish the risk associated with developing this capability;
- outline the technical and functional aspects of the proposed concept;
- assess the advantages and disadvantages of such an approach.

3. Methodology

The approach used to accomplish the stated objectives will involve:

- specification of the general concept;
- review of the individual concept technologies as they exist today;
- detailed examination of the concept and its unique technology;
- functional lay down of the proposed system.

B. CONCEPT PROPOSAL

1. Overview

Again, the specific command and control requirement is to generate and display identification, position, and tactical information on U.S. combat forces. This near real time display will aid the execution of current operations and support planning for future operations. Both of these missions must be accomplished within the tenets of AirLand

Battle (ALB) doctrine. Fielding of this capability would significantly enhance the operational effectiveness of tactical U.S. combat forces. [Ref. 30:p. 13]

The OMEGA/Transponder concept proposes to capitalize on the demonstrated strengths of very low frequency (VLF) radio systems, radar beacon system (RBS) and computer technologies to address a stated command and control deficiency. Specifically, the OMEGA/Transponder concept expects to capitalize on the technical strengths of the OMEGA Radionavigation System, the Navy's VLF Communication System (VLF COMM) and the Department of Defense Identification Friend or Foe System to generate and display friendly force disposition to enhance the command and control process. [Ref. 30:pp. 1-2]

This chapter will extend the concept to allow for discussion of the more critical operational and organizational considerations. This will all be accomplished within the context of applicable Army command and control programs.

For the purposes of this discussion, the OMEGA/Transponder concept will be referred to as VLF/IFF. The reasons for this will become clear in the early sections of this chapter.

2. Technologies

VLF/IFF technologies currently support a strategic communication system and two internationally operated systems each providing service to thousands of civil and military subscribers. Both systems are designed to support joint and combined operations in peacetime and wartime environments.

Figure 17 shows that both of these technologies have many years of evolutionary development and millions of dollars invested to ensure technical reliability. The marriage of these technologies in VLF/IFF will reap the benefits of these investments for little additional expense. [Ref. 31:p. 3.33]

The associated risk of such a technical effort is low due to the availability of many of the components needed for VLF/IFF. It is estimated that greater than 80% of the needed components are already in production. The other 20% could be provided with minor hardware modification and standard software development efforts. [Ref. 31:p. 3.34]

Low cost, low risk, and 'off the shelf' components will ensure an accelerated development cycle. This in turn will guarantee near term fielding of this needed capability to tactical units concerned with fighting today's battles. [Ref. 31:p. 3.5]

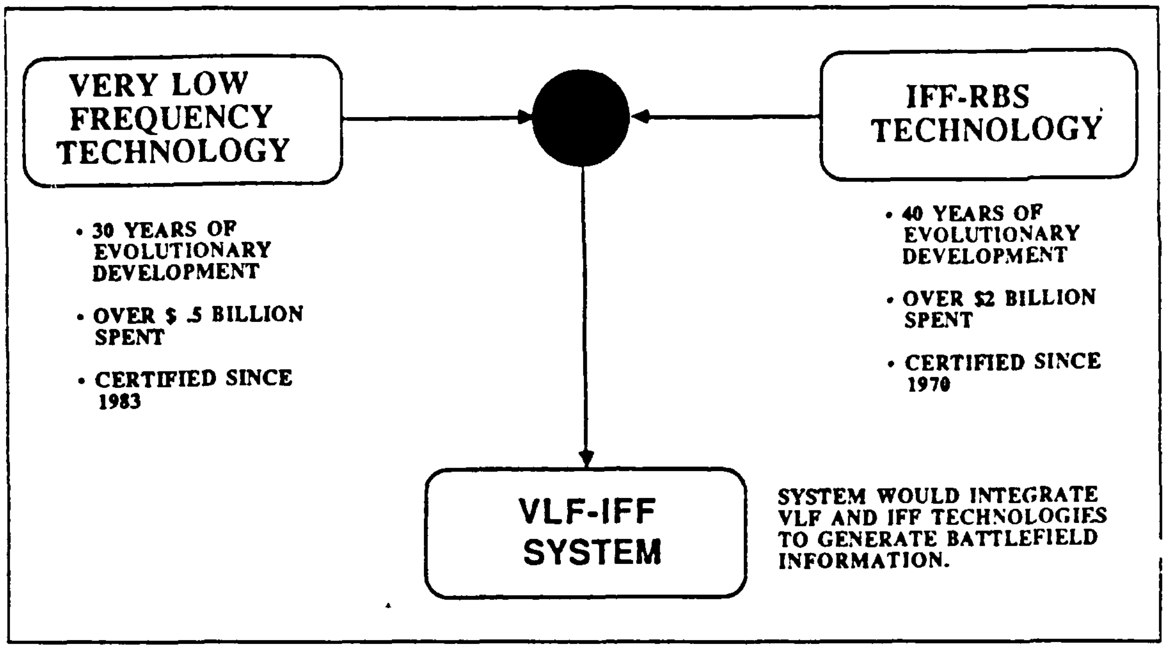

Figure 17. VLF/IFF Technology Integration

3. Operational Considerations

The global and international nature of the VLF and IFF systems will support worldwide operation. The robust, redundant capacity of these systems will enhance tactical operations across the spectrum of anticipated battlefield environments. The stand alone nature of VLF/IFF will support rapid deployment. The precise timing of the VLF signal will provide for battlefield synchronization of all friendly combat elements through reference to a common positional grid. VLF/IFF will enhance command post survivability through the use of passive techniques. [Ref. 30:p. 13]

C. THE IDENTIFICATION FRIEND OR FOE (IFF) SYSTEM

1. Background

The IFF system is the military extension of the Civil Air Traffic Control Radar Beacon System (ATCRBS). Both systems share common RBS technologies whose evolutionary development dates back to World War II. The electrical characteristics of the two systems are essentially the same. It is this feature that guarantees civil/military interoperability. [Ref. 32:p. 138]

To ensure the cooperation needed between the numerous international users of this technology, standards have been developed by the International Civil Aviation Organization (ICAO), which is a subsidiary of the United Nations. Furthermore, within

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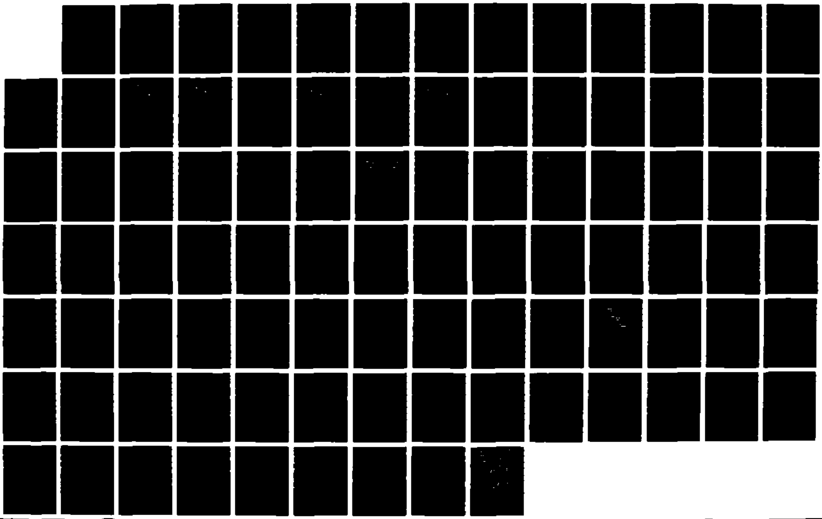

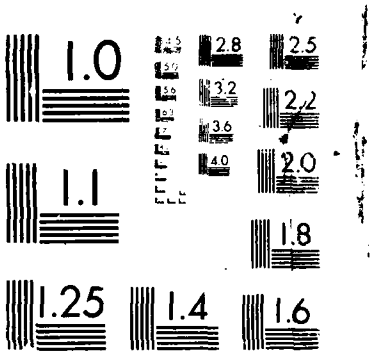

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

the United States, the Federal Aviation Agency is responsible for developing regulations for civil and DOD users. The relationship between these organizations is depicted in Figure 18. The Radio Technical Commission for Aeronautics (RTCA) develops transponder specifications and Airlines Radio Incorporated (ARINC) publishes a special specification for the transponder. [Ref. 32:pp. 133-134]

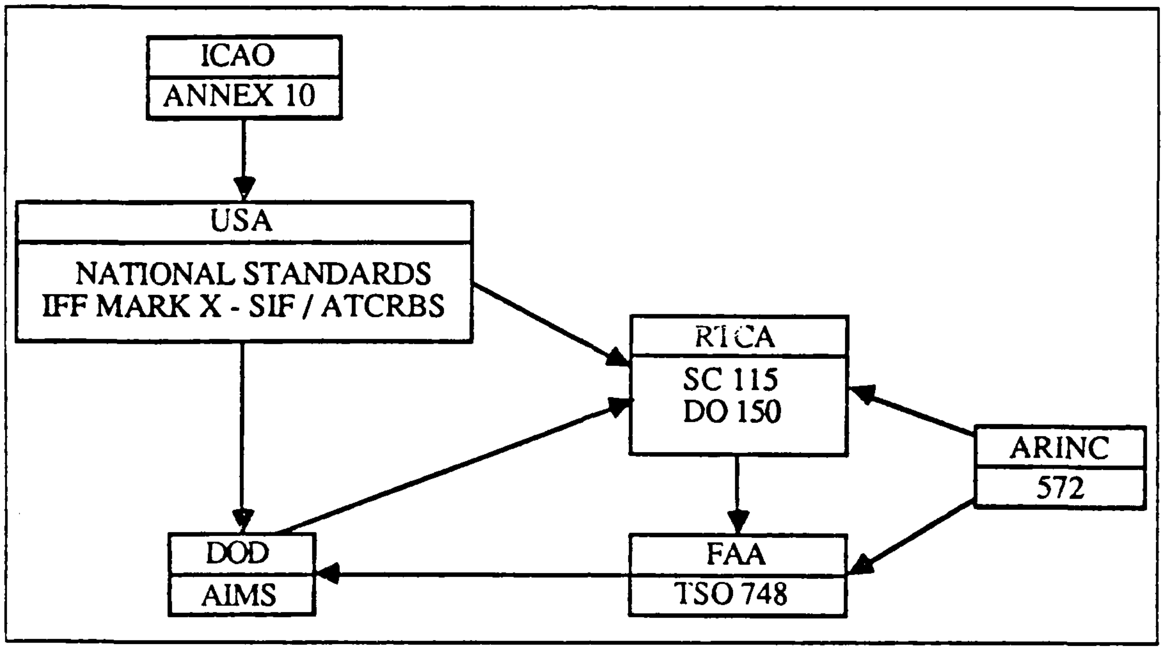

Figure 18. IFF/ATCRBS Standardization

IFF transponder technology is employed in all U.S. and allied military aircraft. The current U.S. transponder is designated the Mark XII. The Army currently employs two models of the Mark XII. They are the AN/TPX-72 and the AN/TPX-100. The majority of U.S. allies use the Mark X transponder. [Ref. 33:pp. 150-152]

The major difference between the Mark X and the Mark XII is that the Mark XII has an encryption capability that the Mark X does not. Otherwise, the versions are fully compatible [Ref. 33:pp. 150-152]. For this reason and due to its implication for combined interoperability, this chapter will use the Mark X as a vehicle for discussion. System specifications for the Mark X transponder are shown in Table 3 on page 82 [Ref. 32:p. 20].

The Mark XV is currently being developed as the next generation of IFF transponders. Recent agreement between the NATO Defense Ministers has selected the Mark XV transponder as the standard for use in the NATO Identification system (NIS).

Table 3. CHARACTERISTICS OF THE MARK X SYSTEM

Range of system	370 kilometers
Frequency band	L-Band
Interrogator frequency	1030 MHz
Interrogator wavelength	29.0 cm
Transponder frequency	1090 MHz
Transponder wavelength	27.5 cm
Transmitter peak pulse power:	
Interrogator	1500 Watts
Transponder	500 Watts
Receiver sensitivity:	
Interrogator	-82 dBm
Transponder	-75 dBm
Pulse rise time	$\leq$ 100 ns
Video bandwidth	5 MHz (approximation)
Antennae:	
Interrogator	Directional
Transponder	Omni-directional
Polarization	Vertical

The Mark XV incorporates improved performance and security characteristics. As the Mark XV is introduced into operation it will function alongside and remain compatible with the Mark X and Mark XII versions. The VLF/IFF concept will work with any version of these transponders. [Ref. 33:pp. 150-152]

2. System Operation

The IFF system uses secondary surveillance radar (SSR) signals to determine identification, range, azimuth, elevation and other operational information for a specific maneuver element. Azimuth to a maneuver element is taken from an antenna pointer.

Range is determined by the time it takes an interrogation signal to travel to a maneuver element plus the time it takes the maneuver element's transponder reply to return to the interrogating station. This is a cooperative process that involves an electronic signal exchange as opposed to using passive primary radar reflection techniques. [Ref. 34:p. 38.1]

In this system, a two way data link is established between an interrogating station and a responding station on separate transmitting and receiving frequencies. The interrogating station effectively asks a question which the responding station answers. The advantages of a cooperative system like this over primary radar are:

- reply pulses are stronger;
- separate transmitting and receiving frequencies eliminate ground clutter and weather return problems;
- interrogation and reply path coding provide discrete target identification and altitude reporting. [Ref. 33:pp. 38]

3. Signal Format

The IFF system operates in the ultra high frequency (UHF) band of the electromagnetic spectrum with the interrogation signal at 1030 MHz and the response signal at 1090 MHz. As with all UHF systems, IFF is a line of sight system. [Ref. 33:p. 38.2]

Both interrogation and response signals use pulse position modulation. A depiction of the pulse employed is shown in Figure 19 [Ref. 32:p. 23].

Each 1090 MHz reply pulse is characterized by a very short rise time of 50 ns. Each pulse has a specified duration of 0.45 μs with a tolerance of 0.1 μs [Ref. 32:p. 23]. Because of the requirement for fine reproduction of the IFF signal, which is necessary to determine precise ranges, rise time is used to calculate transmission bandwidth. The transmission bandwidth of the IFF signal is calculated as shown in equation 3.1. [Ref. 35:pp. 115-116]

$$B_T = \frac{1}{\text{rise time}} = \frac{1}{50 \times 10^{-9}\ \text{sec}} = 2 \times 10^7 Hz = 20 MHz \tag{3.1}$$

The signal format or 'mode' of the interrogation signal determines the coding of the transponder reply [Ref. 34:pp. 38.2-38.4]. Each of these signals will be discussed in more detail later in this chapter.

Peak pulse power of the interrogator signal is typically 1 to 1.5 kW. Standard peak pulse power of the transponder reply is 500 W [Ref. 32:p. 20].

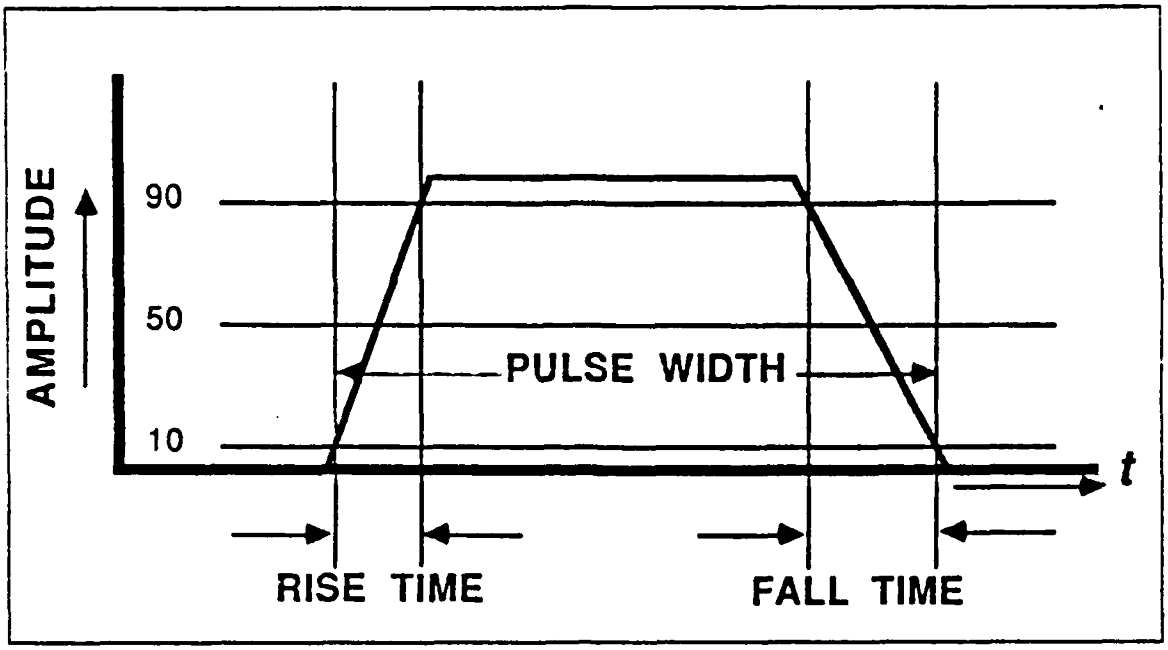

Figure 19. IFF Pulse Format

The interrogator uses a directional antenna with a signal beamwidth of 2.8 to 7.0 degrees and vertical polarization. The transponder uses an omni-directional antenna with vertical polarization. [Ref. 34:p. 38.3]

a. Interrogation Signal

The various interrogation signal formats, or modes, are depicted in Figure 20 [Ref. 32:pp. 21-22]. Each mode is defined by the time interval between the P_1 and P_3 pulses. Each mode effectively demands specific information to be encoded in the transponder reply. For instance, Mode 3/A requires the transponder to reply with the maneuver element's unique identity code. Mode C requires the transponder to reply with the encoded altitude of the maneuver element. [Ref. 32:p. 22]

Each mode is reserved for specific operational communities. Modes 1 and 2 are reserved for military use. Modes B and D are reserved for civil air traffic control (ATC). Modes 3/A and C are shared by the military and civil communities, thereby ensuring IFF/ATCRBS interoperability. Although not shown, there is a Mode 4 which is reserved for use by the military for Mark XII encryption [Ref. 33:pp. 150-152]. Mode 4 will not be addressed in this discussion except to say that it can be used in the VLF/IFF concept to enhance the security of the system.

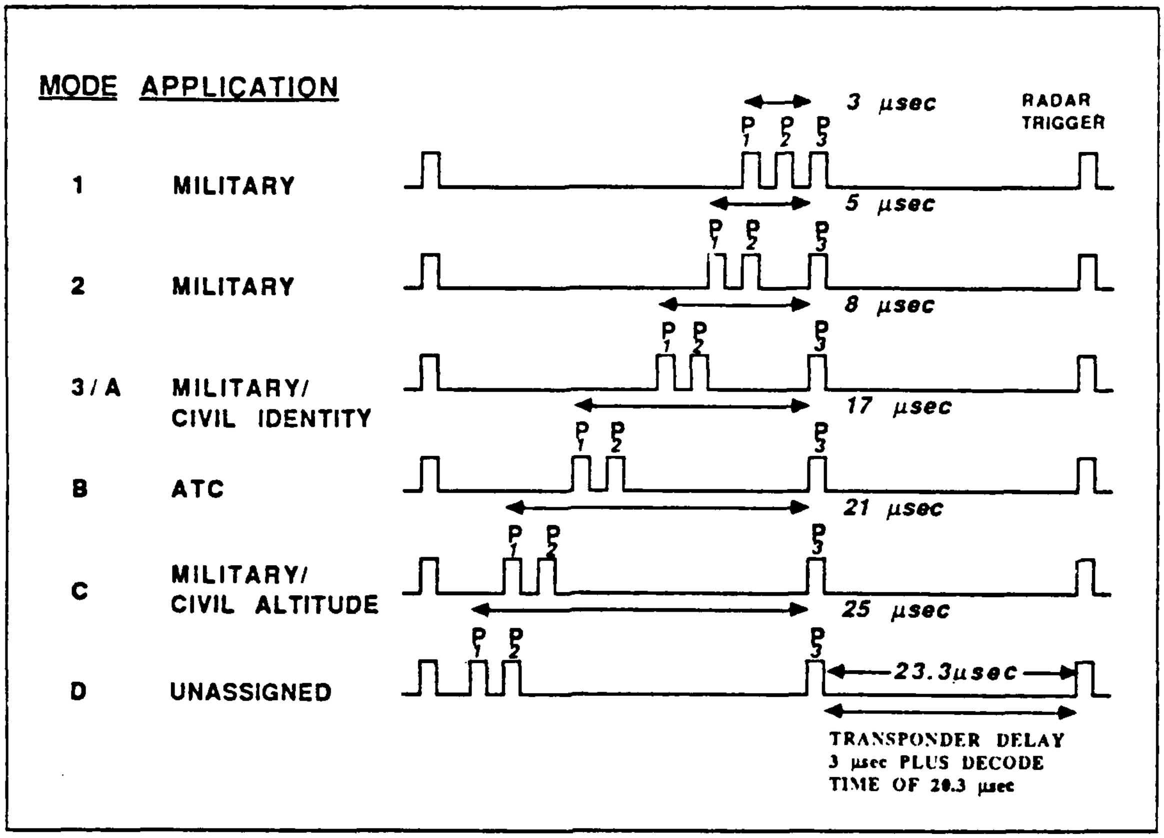

Figure 20. Interrogation Signal Format

b. Response Signal

The response signal format is depicted in Figure 21. As stated earlier, the signal uses pulse position modulation in the sense that information in the signal is dependent on the presence or absence of the pulses in specific positions in a frame. There are specified pulse positions at 1.45 μs intervals as indicated. The duration of the response signal is 20.3 μs with a tolerance of 0.1 μs. [Ref. 32:p. 23]

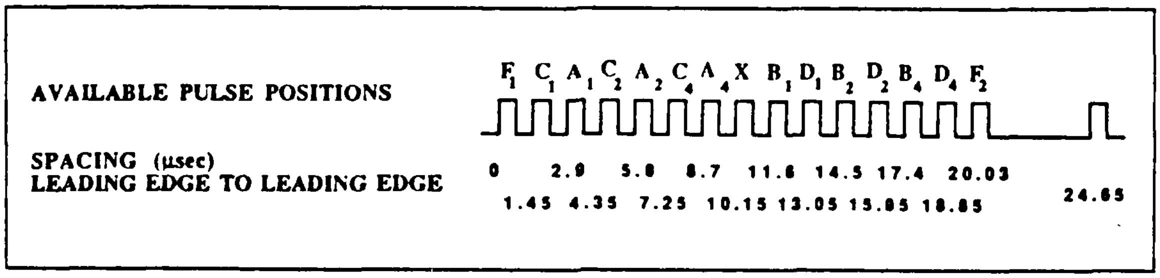

Figure 21. Response Signal Format

The typical transponder can reply 1,200 times per second [Ref. 34:p. 38.12]. The short length of the reply and the number of replies possible per second provides for a very robust system supporting many users and the exchange of a large amount of information.

The first and last pulses of the signal are framing pulses and are always present. The 'X pulse' or center pulse is always an empty position. The other twelve pulses are the information pulses which provide 2^{12} or 4,096 possible code words. [Ref. 34:p. 38.3]

These code words are used primarily to assign unique identity to a maneuver element and report altitude. Altitude is reported in terms of flight levels or 100 foot increments of standard atmosphere. Special code words are currently reserved to transmit operational and emergency situation information. [Ref. 34:p. 38.3]

Possible enhancements to the system that will be discussed as they apply to the VLF/IFF concept include:

- using the X pulse to provide for additional code words, i.e., 2^{13} or 8,192 code words per mode;
- a data link capability between the ground station and the transponder;
- an address coded, selective interrogation system. [Ref. 32:p. 74]

D. THE OMEGA AND VLF COMMUNICATION SYSTEMS

The OMEGA and VLF Communications (VLF COMM) systems are two independent systems with different missions both operating in the very low frequency (VLF) or 10 to 30 kHz region of the electromagnetic spectrum. For the purposes of this paper, VLF will be used to describe a generic 10 to 30 kHz signal. Distinctions between the OMEGA and VLF COMM signals will be specified as required.

1. OMEGA

OMEGA is a hyperbolic radionavigation system operating on a timesharing basis with eight stations transmitting phase synchronized signals in the VLF range of the electromagnetic spectrum. The VLF band between 9 and 14 kHz has been internationally reserved for operation of the OMEGA system. The system is designed to provide aircraft and ships with continuous, all weather, position fixing accuracy of 4 nautical miles, 95% of the time. [Ref. 36:p. 1]

Due to the characteristics of the system's signal, OMEGA is exceptionally well suited for use over enormous distances, at all altitudes and all surface locations regard-

less of terrain. There is no line of sight requirement for use of OMEGA. [Ref. 36:p. 2]

The OMEGA system was developed by the United States and is currently operated in a partnership with Norway, Liberia, France, Argentina, Australia, and Japan. The locations of the OMEGA stations are shown in Figure 22 while operating agencies for each station are listed in Table 4 on page 88. [Ref. 36:pp. 1-2]

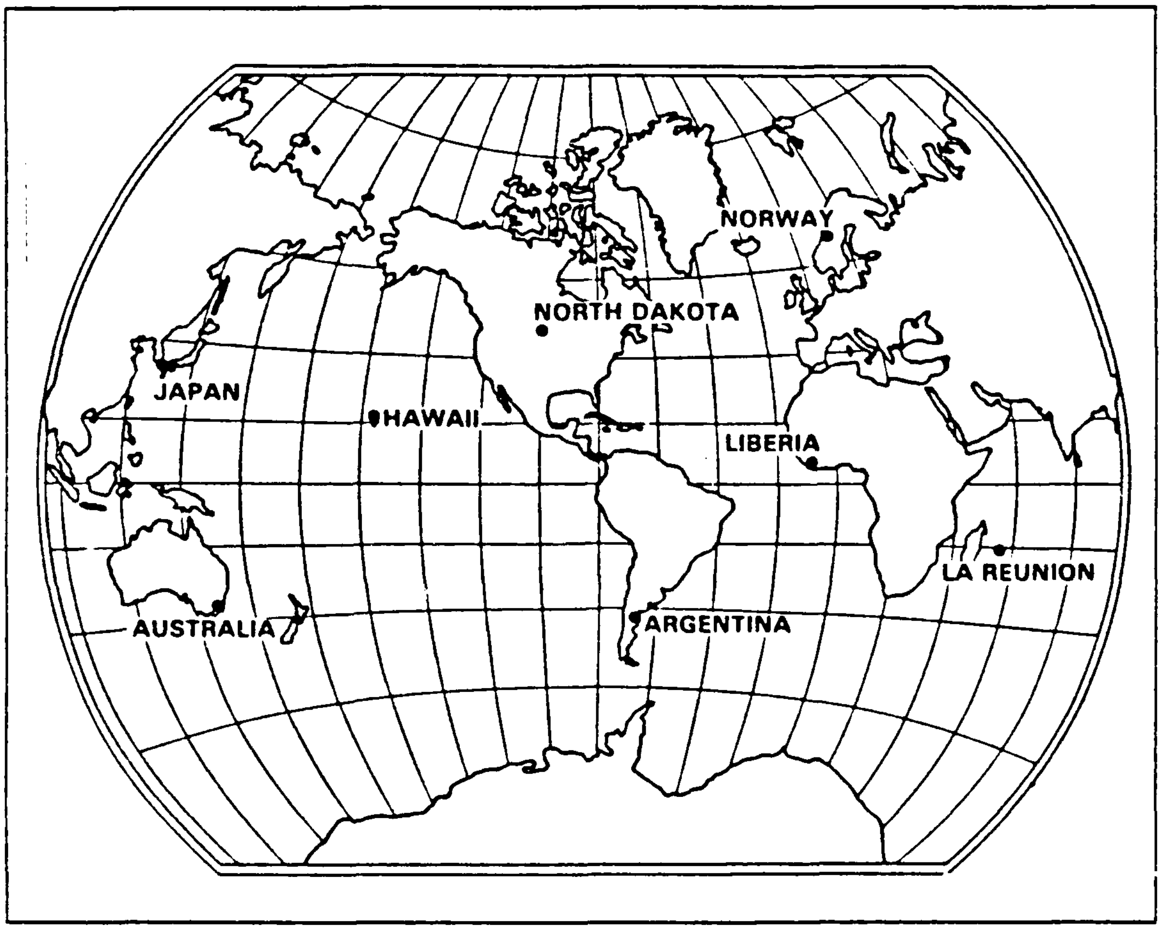

Figure 22. OMEGA Station Locations

The OMEGA system has been certified and fully operational as a global navigation system since 1982. It is currently the only continuous operation global navigation system in the world. [Ref. 37:p. 467]

Signal synchronization is the cornerstone of the OMEGA system. For the system to operate properly, the precise OMEGA timing sequence must remain stable. This

Table 4. OMEGA STATION OPERATING AGENCIES

STATION:	LETTER DESIGNATION:	COORDINATES:	OPERATOR:
Norway	A	66 25 12.62N 13 08 12.52E	Norwegian Telecommunication Administration (NTA)
Liberia	B	06 18 19.11N 10 39 52.40W	Liberian Ministry of Commerce, Industry, and Transportation
USA:			
Oahu, HI	C	21 24 16.78N 157 49 51.51W	U.S.C.G.
La Moure, ND	D	46 21 57.29N 98 20 08.77W	U.S.C.G.
La Reunion Is.	E	20 58 27.03S 55 17 23.07E	French Navy
Argentina	F	43 03 12.89S 65 11 27.36W	Argentine Navy
Australia	G	38 28 52.53S 146 56 06.51E	Australian Department of Transport
Japan	H	34 36 52.93N 129 27 12.57E	Japanese Maritime Safety Agency (JMSA)

is accomplished through the use of three cesium frequency standards located at each OMEGA station. [Ref. 36:p. 7]

The OMEGA signal format is shown in Figure 23. The signal radiated by each transmitter is a sequence of continuous wave radio frequency transmissions lasting between 0.9 and 1.2 seconds. Each 'burst' transmission contains over 10,000 precision zero phase crossings. These pulses are separated by 0.2 second silent intervals. [Ref. 36:p. 6]

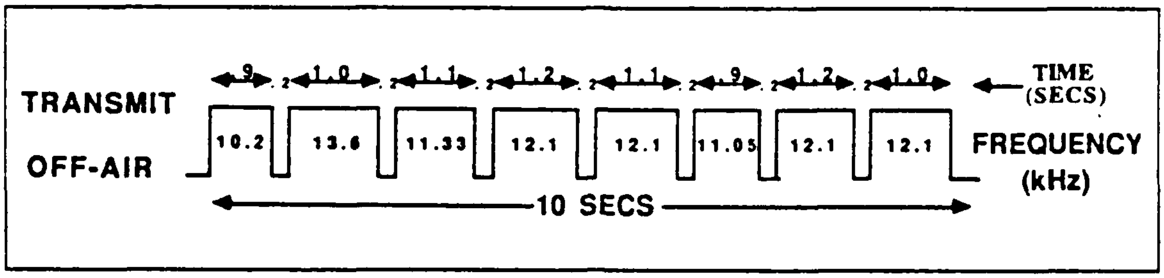

Figure 23. OMEGA Station 'A' Signal Format

Each station's signal consists of five frequencies transmitted in an eight pulse pattern of various time periods over a ten second interval. Four of these frequencies, which are used for navigation, are shared by each station. These 'navigation' frequencies are 10.2, 11.05, 11.33, and 13.6 kHz. In addition to the navigation frequencies, each station transmits a unique identification frequency. The unique station identity frequencies and the letter designation for each station are shown in Table 5. [Ref. 36.p. 6]

Table 5. OMEGA IDENTITY FREQUENCIES

STATION:	LETTER DESIGNATION:	FREQUENCY (kHz):
Norway	A	12.1
Liberia	B	12.0
USA:		
Hawaii	C	11.8
N. Dakota	D	13.1
La Reunion Is.	E	12.3
Argentina	F	12.9
Australia	G	13.0
Japan	H	12.8

These shared and unique identity frequencies are transmitted in a specified sequence that allows a receiver to determine a particular OMEGA station's signal. This OMEGA system signal 'key' is shown in Figure 24. Synchronization of an OMEGA receiver to the OMEGA key is essential for use of this system. [Ref. 36:p. 7]

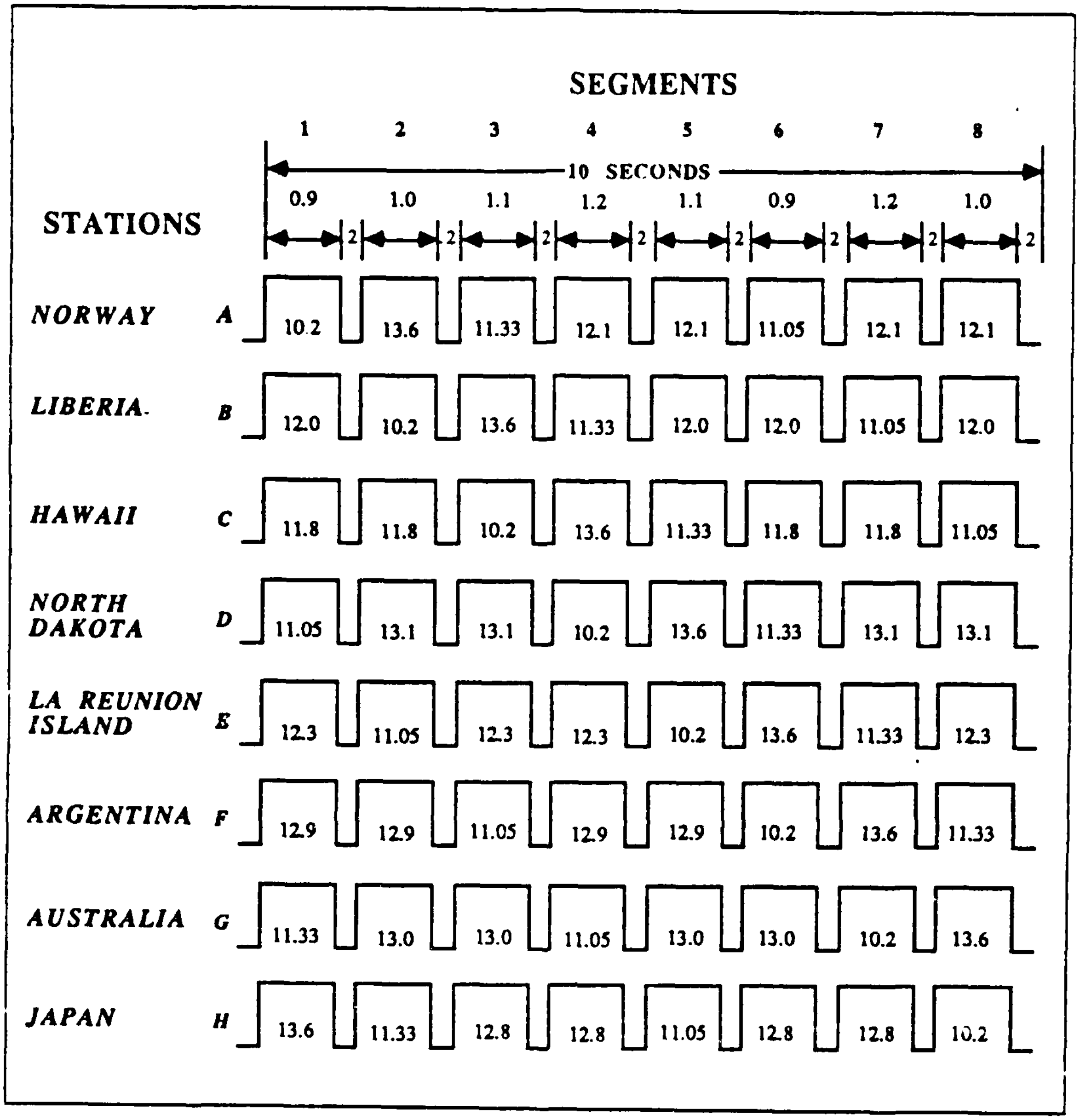

Figure 24. OMEGA Signal Transmission Key

OMEGA navigation is performed by measuring the phase difference of like frequency signals from three different stations. The measured phase difference between two OMEGA station signals, say at 10.2 kHz, determines a line of position (LOP) between the two stations on which the receiver must lie. Measurement of phase differences between several OMEGA stations defines additional LOP's. The intersection of these LOP's is used to determine receiver location. [Ref. 36:pp. 13-14]

An OMEGA station generates 150 kW of signal power. However the OMEGA transmitter's average radiated signal power is 10 kW [Ref. 37:p. 467]. This is a result of the inefficiency of the huge antenna necessary for signal transmission. This 10 kW signal power precludes interference caused by signals traveling twice the circumference of the earth. It also means that not all station signals are available everywhere in the world. However, receipt of at least three to four usable signals has been demonstrated by extensive survey over 95% of the earth's surface. This is sufficient for global navigation. [Ref. 38:pp. 22-25]

The angle of arrival of these signals is important in determining position accuracy. Because of the geographic locations of the eight OMEGA stations, the arrival angle of the signals is sufficiently distributed over 360 degrees to minimize geometric dilution of position (GDOP) or errors that are introduced when the angle between intersecting signal lines is significantly less than 90 degrees. [Ref. 37:pp. 471-472]

The OMEGA Radionavigation System is currently being used for various missions by all departments of the U.S. Armed Forces and by most of our allies. The system is also used extensively by commercial airline and maritime industries. A survey conducted between 1984 and 1986 identified over 15,000 users of the OMEGA system [Ref. 39:pp. 186-196]. That number represents a significant increase over the past six years. Much of this increase can be attributed to demonstrated improvements in system accuracy and reliability [Ref. 38:pp. 8-14].

In addition to the global OMEGA system, there are a series of differential OMEGA stations, located for the most part in Europe. These stations correct for propagation effects on the global VLF signals. This service is available for receivers within several hundred kilometers of these stations. Differential OMEGA will not be discussed in this paper. [Ref. 36:p. C.1]

2. VLF COMM

The primary mission of the VLF COMM System is to support the submarine forces of the United States nuclear triad. There are ten U.S. and allied VLF COMM stations located around the world as depicted in Figure 25 [Ref. 40:p. 122]. Seven of these stations are U.S. owned and operated by the U.S. Navy [Ref. 41:p. 18]. Many of these station's signals are currently being used by commercial OMEGA receivers to augment the OMEGA signals. [Ref. 42:pp. 8-14]

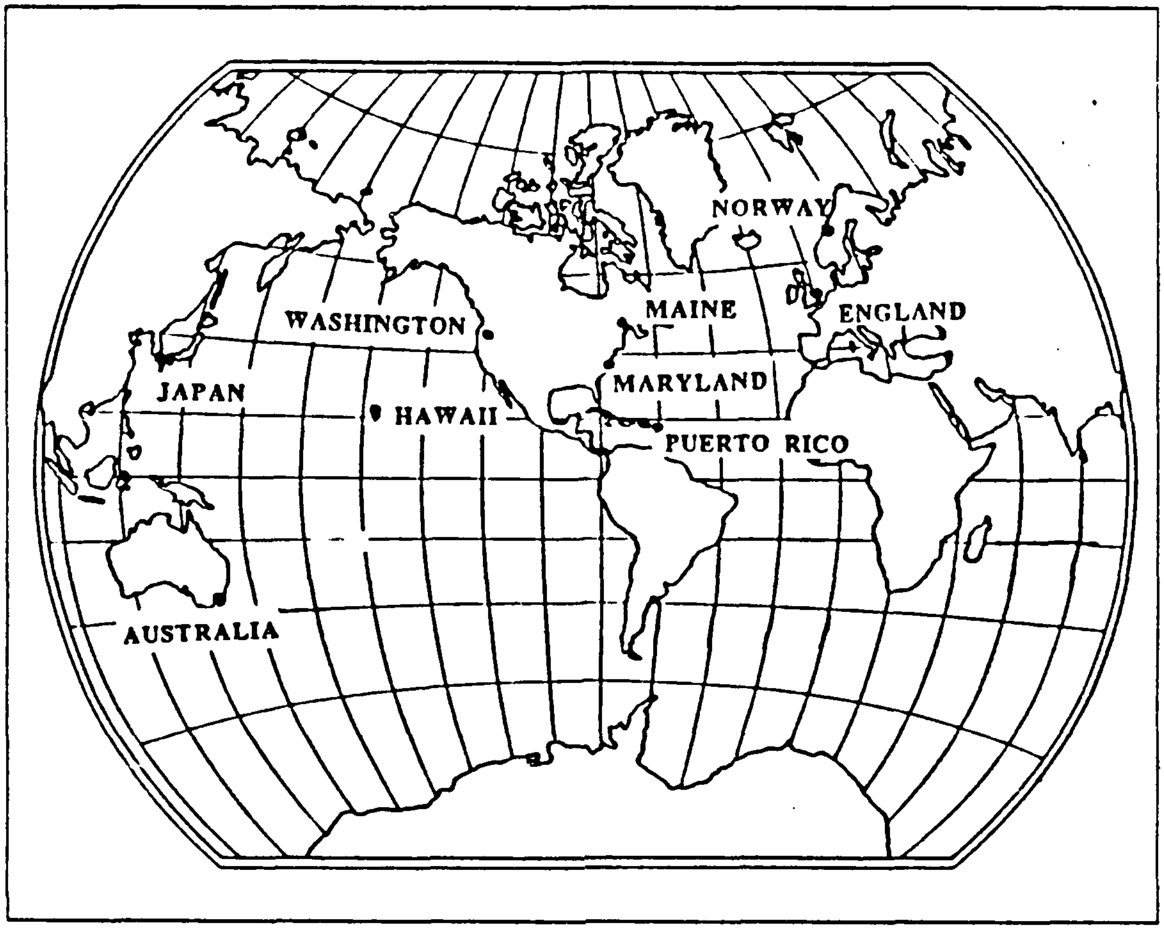

Figure 25. VLF COMM Station Locations

The VLF COMM stations operate in the VLF part of the electromagnetic spectrum between 15 and 30 kHz. Specific station and frequency match ups are shown in Table 6 on page 93. [Ref. 41:p. 18]

Unlike OMEGA, each VLF COMM station transmits continuously on only one frequency. In addition, the power output of the VLF COMM transmitters is 100 to 1000 kW. [Ref. 40:p. 129]

VLF COMM stations also use cesium standards resulting in extremely frequency and phase stable signals. These stations employ frequency-shift keying (FSK) to modulate the signals. For the purpose of this paper, we will limit our discussion to the timing and phase stability aspects of the VLF COMM System. [Ref. 40:p. 129]

The Soviets also have navigation and communication stations operating in the VLF spectrum. They have three navigation stations operating at 11.905, 12.649, and

Table 6. VLF COMM STATION SIGNAL FREQUENCIES

	LOCATION:	CALL SIGN:	FREQUENCY(kHz):
U.S.:			
	Maine	NAA	24.0
	Washington State	NLK	24.8
	Maryland	NSS	21.4
	Hawaii	NPM	23.4
	Puerto Rico	NAU	28.5
	Australia	NWC	22.3
	Japan	NDT	17.4
Allied:			
	Norway	JXN	16.4
	England	GBZ	19.0
	England	GBR	16.0

14.881 kHz [Ref. 40:pp. 128-129]. The Soviets currently operate approximately 30 VLF COMM stations for control of their submarines. These stations operate in the 15-30 kHz range with transmission power between 400 and 500 kW [Ref. 43:p. 71].

U.S. VLF COMM signals are currently being used by most OMEGA receivers as an additional signal source. An advantage of doing this is the increased signal to noise ratio (S/N) due to the VLF COMM's greater output power. [Ref. 41:pp. 16-20]

E. VLF/IFF TECHNICAL DESCRIPTION

VLF/IFF proposes to use the IFF transponder without modification. This will provide command and control display information without interfering with the traditional ATC/Air Defense (AD) function of the transponder. VLF signals, either OMEGA or VLF COMM, will be used in a non traditional manner. The VLF signal will be used, in this concept, for time synchronization. That is, VLF/IFF is not concerned with phase differences between like frequencies from two different stations. Additionally, the OMEGA and VLF COMM signals will be used one at a time, not in pairs, in a relative manner over a small (50 x 100 km) geographic area. This is significantly different from how OMEGA is currently being used in the global sense. This technique effectively eliminates the adverse effects of long distance propagation disturbances that contribute to conventional OMEGA navigation errors. [Ref. 30:p. 7]

The VLF/IFF concept envisions a tactical battlefield saturated, both on the ground and in the air, with precision timed VLF signals from at least three to four OMEGA and/or VLF COMM stations [Ref. 30:p. 12]. Maneuver elements will be equipped with a VLF receiver/IFF transponder set [Ref. 31:p. 4.7]. Command and control nodes will be equipped with a C2 element consisting of a VLF/IFF receiver and display processor [Ref. 31:p. 4.11].

It is important to note at this point that, the VLF receiver is not a full OMEGA navigation set. Much of what is necessary for OMEGA navigation can be removed from the receiver for VLF/IFF. This is due to VLF/IFF use of the OMEGA and VLF COMM signals for precise timing only and not for navigation purposes.

The VLF signals will be used to define precise timing periods by the command and control elements and to trigger the transponders on maneuver elements, thereby synchronizing and locking all players, air and ground, to a common reference grid. The IFF transponder signals transmit unique identification, position, and tactical intelligence to the command and control element for processing and display. [Ref. 30:pp. 2-3]

1. TIME OF ARRIVAL

In the VLF/IFF approach, time of arrival (TOA) is defined as the time it takes a VLF wave front from a distant station to pass through a command and control element, travel to a maneuver element, trigger the maneuver element's transponder, and that transponder's signal to return to the command and control element. TOA, therefore is a time interval. Figure 26 illustrates this concept [Ref. 30:Fig. 1].

The beginning of this wave front is defined by the VLF signal's zero phase crossing. All timing measurements in the VLF/IFF system are taken from a signal's zero phase crossing. An example of a VLF signal zero phase crossing is shown in Figure 27. [Ref. 36:p. 9]

In VLF/IFF, the VLF signal is being used to trigger the transponder in place of the active radar generated interrogation signal. This characteristic enables the command and control element to remain passive, thereby enhancing its survivability. [Ref. 30:p. 13]

2. Line of Position

In VLF/IFF, range and azimuth are not determined from a directed electronic beam radiated from the command and control element. As in Figure 28, elliptical geometry is used to calculate an LOP along which the maneuver element must be located. [Ref. 30:Fig. 2]

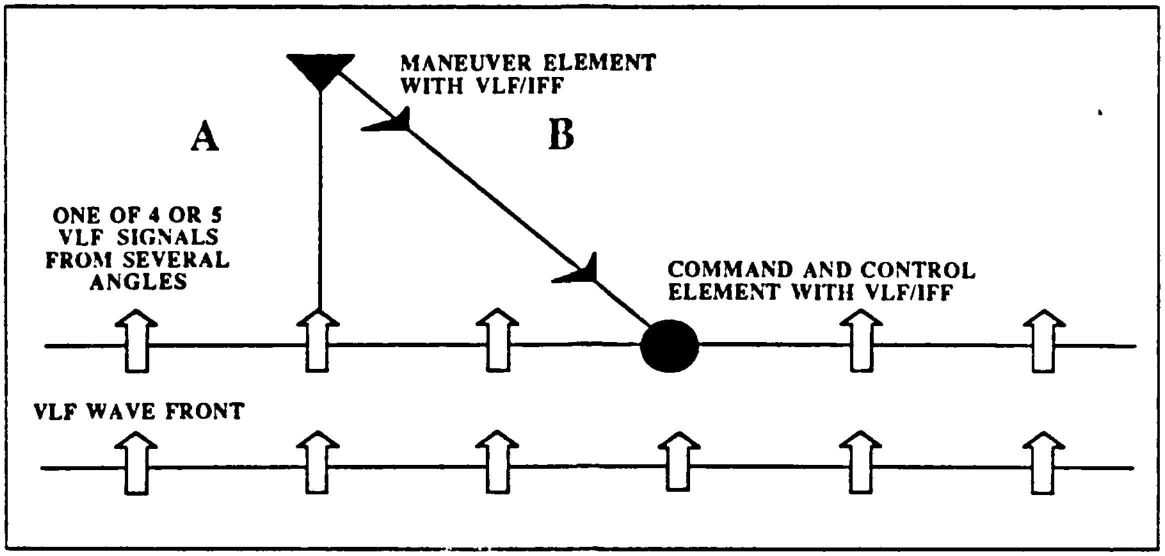

Figure 26. TOA Calculation

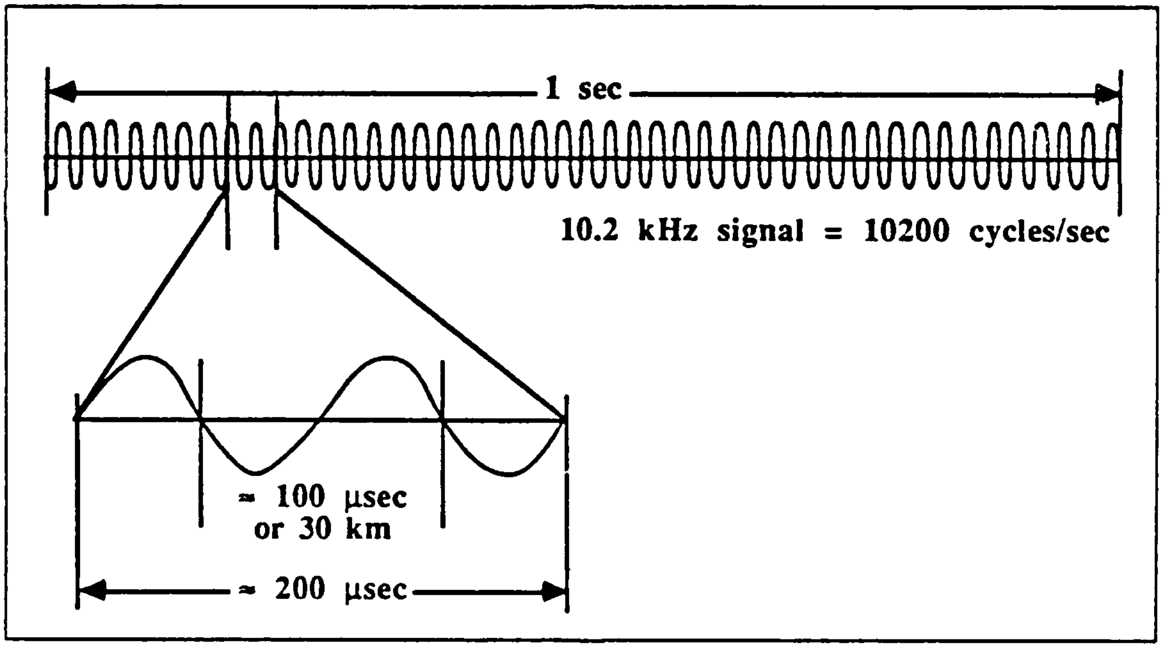

Figure 27. The OMEGA Signal's Zero Phase Crossing

As shown in Figure 29, the command and control element is considered to be one focus of an ellipse, and a VLF station, some 1,000 or more miles away, the other. [Ref. 30:Fig. 3]

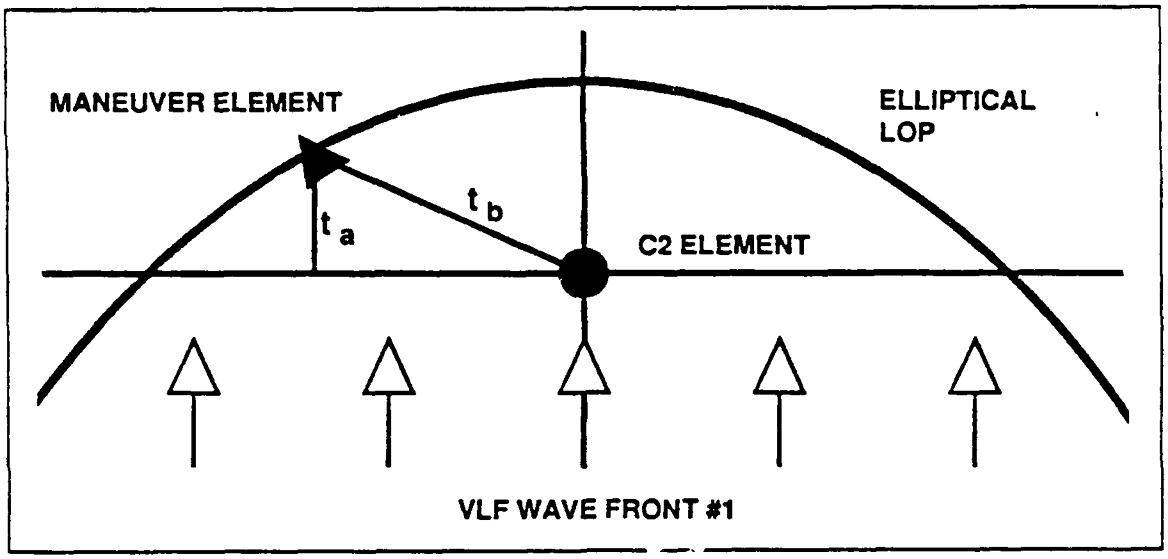

Figure 28. LOP From Single VLF Signal

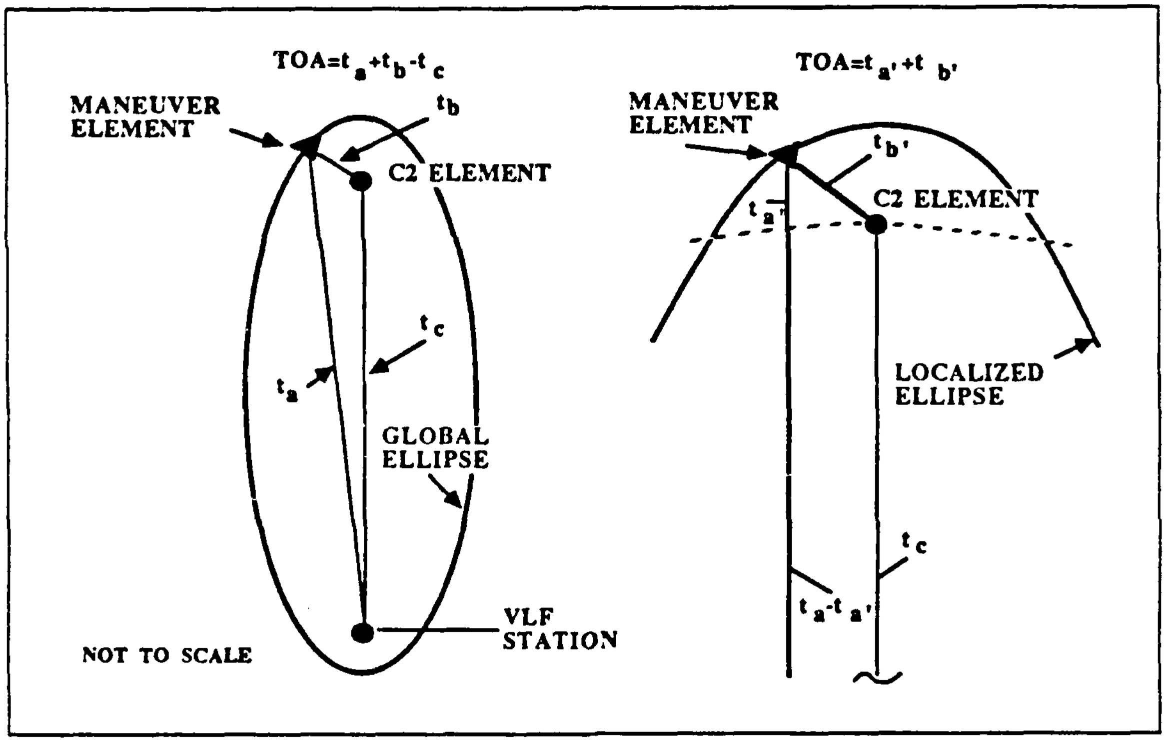

Figure 29. LOP Elliptical Geometry

Figure 30 shows that theoretically there exists a family of LOPs associated with this ellipse. Each LOP is related to a specific TOA defined by a given VLF station. [Ref. 30:Fig. 7]

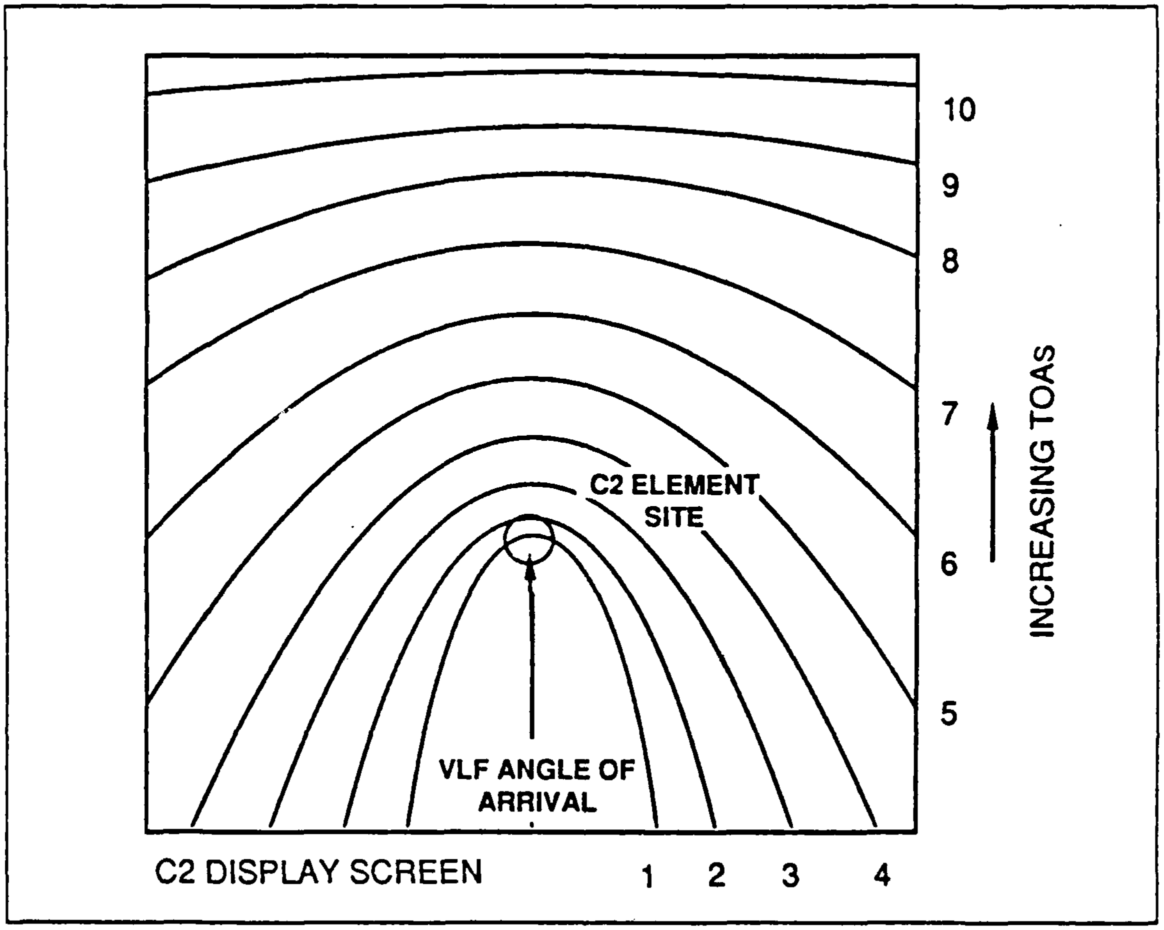

Figure 30. TOA/LOP Relationship

3. Multiple LOP's

For each VLF station and a given TOA, there is a unique LOP. LOPs from two different stations intersect at only two points. This is shown in Figure 31 [Ref. 30:Fig. 6].

A third LOP from a third station, which could be a VLF COMM station, can be used to remove this ambiguity and provide for a precise fix on a maneuver element's true location. Figure 32 demonstrates this point [Ref. 30:Fig. 6].

This technique works for both up range and down range calculations as shown in Figure 33 [Ref. 30:Fig. 5]. Using this approach, only one VLF signal is needed to

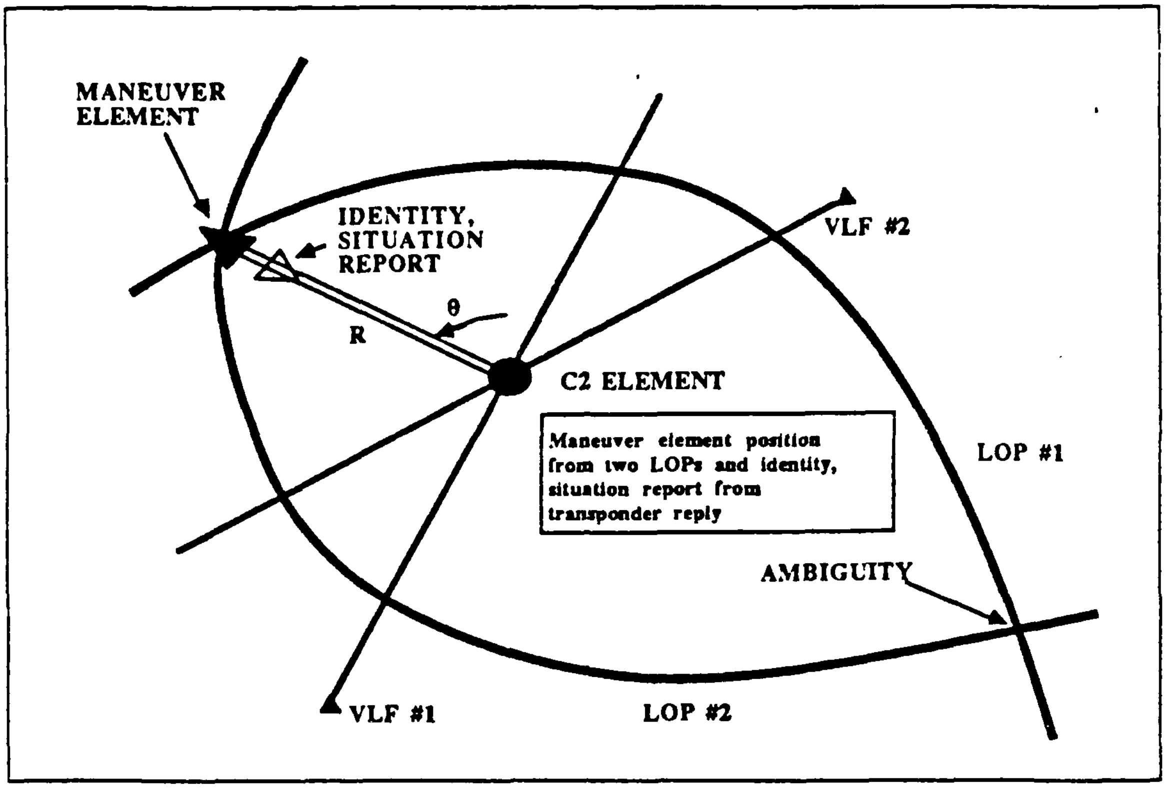

Figure 31. LOP Intersection

generate an LOP as opposed to traditional OMEGA which requires two signals to generate an LOP. [Ref. 30:p. 10]

4. Frequency Combination

Since VLF/IFF uses the VLF signal format to provide it's precision timing, the unambiguous range or TOA measurement of the system is directly related to the frequency of the VLF signal. It is the zero phase crossings of these signals that define the start of the command and control clock and how long before it is reset (i.e., its listening period). Equation 3.2 shows that with a 10.2 kHz signal, zero phase crossings occur approximately every 100 μs [Ref. 35:p. 23].

$$T = \frac{1}{f} = \frac{1}{10.2 \times 10^{3} Hz} = 9.8 \times 10^{-5} \text{ sec } \simeq 100\mu s \tag{3.2}$$

The distance the signal travels in this time is approximately 30 kilometers [Ref. 35:p. 5]. This calculation is shown in equation 3.3.

$$\lambda = c \times T = (3 \times 10^{5} km/\text{ sec}) \times 100\mu s = 30km \tag{3.3}$$

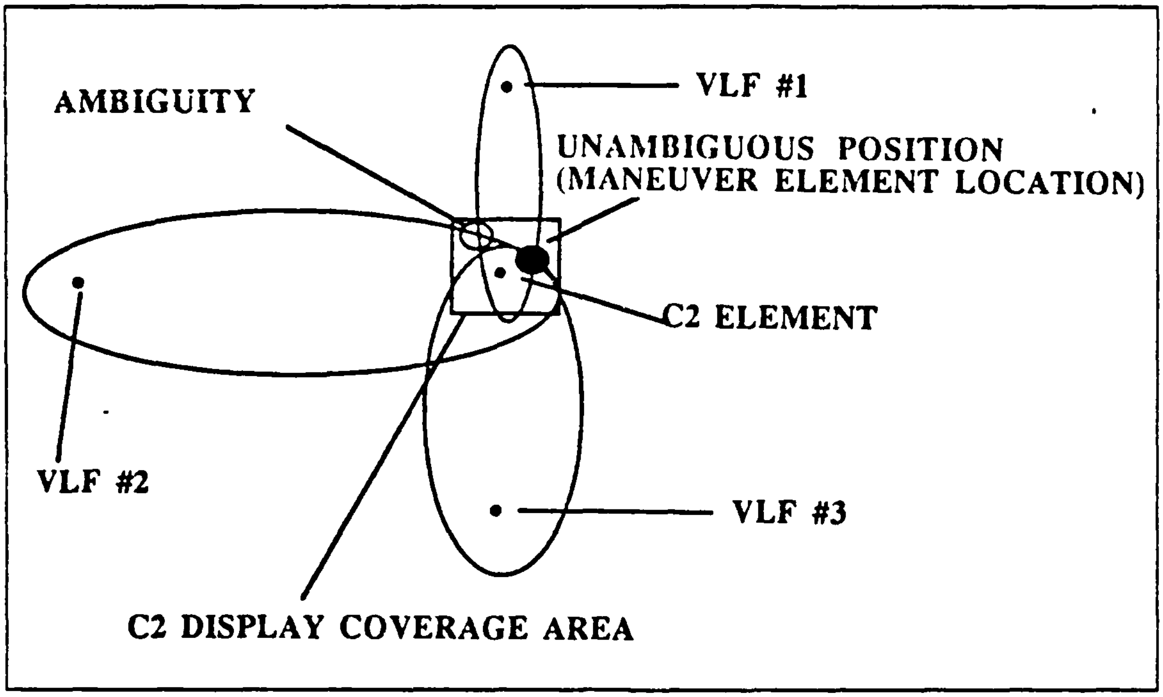

Figure 32. Ambiguity Resolution

Using elliptical geometry and applying these figures to the VLF/IFF system, this equates to a down range distance of 30 kilometers and cross range distance of 60 kilometers. This is illustrated for a single VLF signal in Figure 34 [Ref. 31:p. 3.13].

The same process used above can be applied to the 13.6 kHz signal. With the 13.6 kHz signal, the zero phase crossing occurs approximately every 75 μss and the distance the signal travels is approximately 22.5 kilometers. This decreases the effective up range/down range distance to 22.5 kilometers and the cross range distance to 45 kilometers. These calculations are shown in equations 3.4 and 3.5.

$$T = \frac{1}{f} = \frac{1}{13.6 \times 10^3 Hz} = 7.35 \times 10^{-5} \sec \ \simeq 75\mu s \tag{3.4}$$

$$\lambda = c \times T = (3 \times 10^5 km/\sec) \times 75\mu s = 22.5km \tag{3.5}$$

To further increase the effective range of the system, VLF/IFF proposes using a combination of the 10.2 and 13.6 kHz signals. As shown in Figure 35, coincident zero phase crossing of these signals occur every third and fourth zero crossing, respectively. In effect, this heterodyning creates a 3.4 kHz equivalent signal. [Ref. 31:Fig. 4.5]

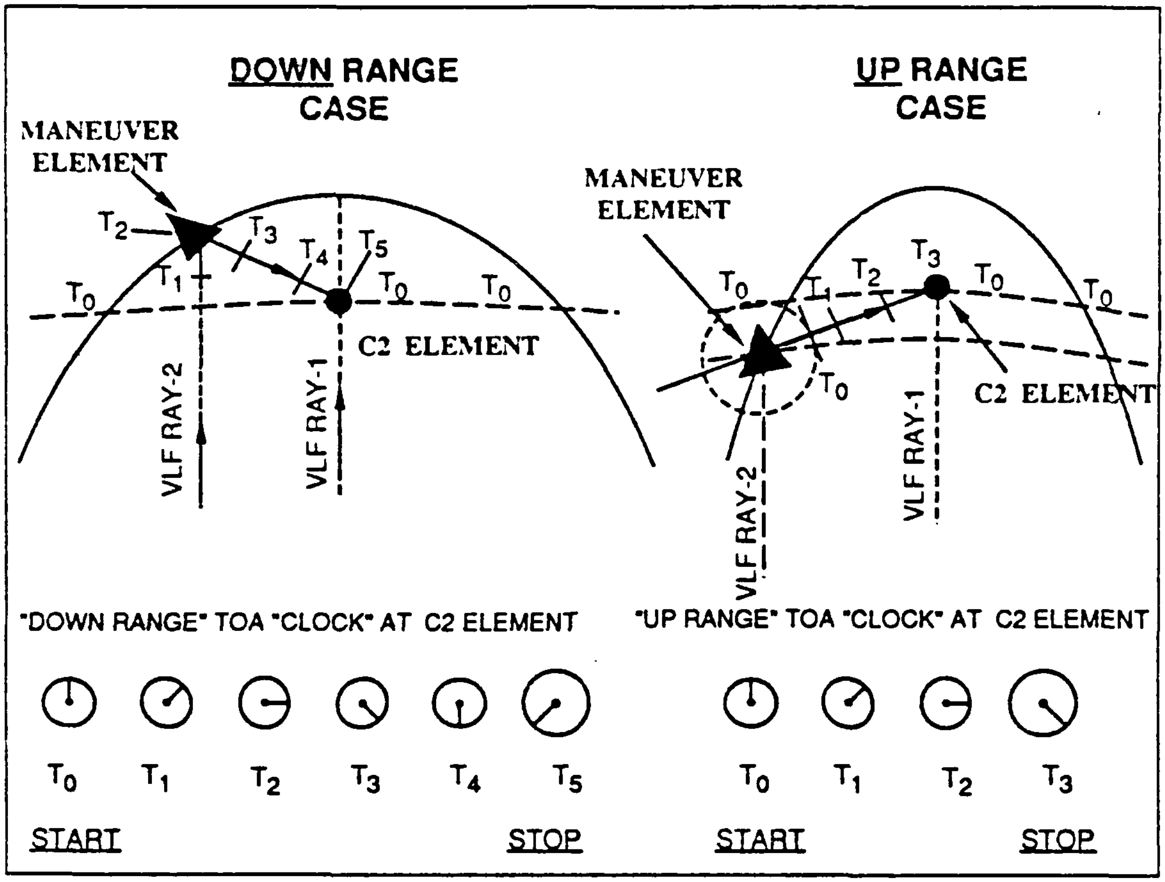

Figure 33. Up Range and Down Range Calculations

Using the zero phase crossings of this 3.4 kHz signal increases both the listening period of the system and the effective range. In this case the listening time is increased to approximately 300 μs and the distance associated with that time is 90 km as shown in equations 3.6 and 3.7.

$$T = \frac{1}{f} = \frac{1}{3.4 \times 10^3 Hz} = 2.94 \times 10^{-4} \text{ sec } \simeq 300\mu s \tag{3.6}$$

$$\lambda = c \times T = (3 \times 10^5 km/ \text{ sec}) \times 300\mu s = 90km \tag{3.7}$$

This equates to an increased down range distance of 90 kilometers and cross range distance to 180 kilometers. The coverage area using these two frequencies is shown in Figure 36.

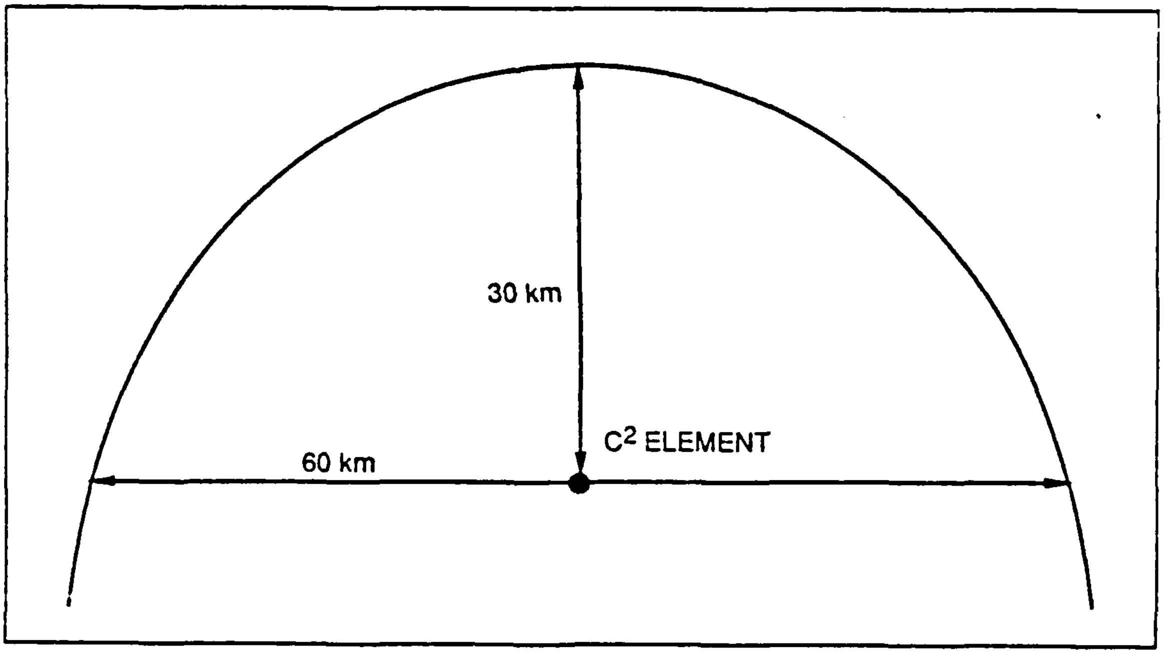

Figure 34. Effective Range of a 10.2 kHz Signal

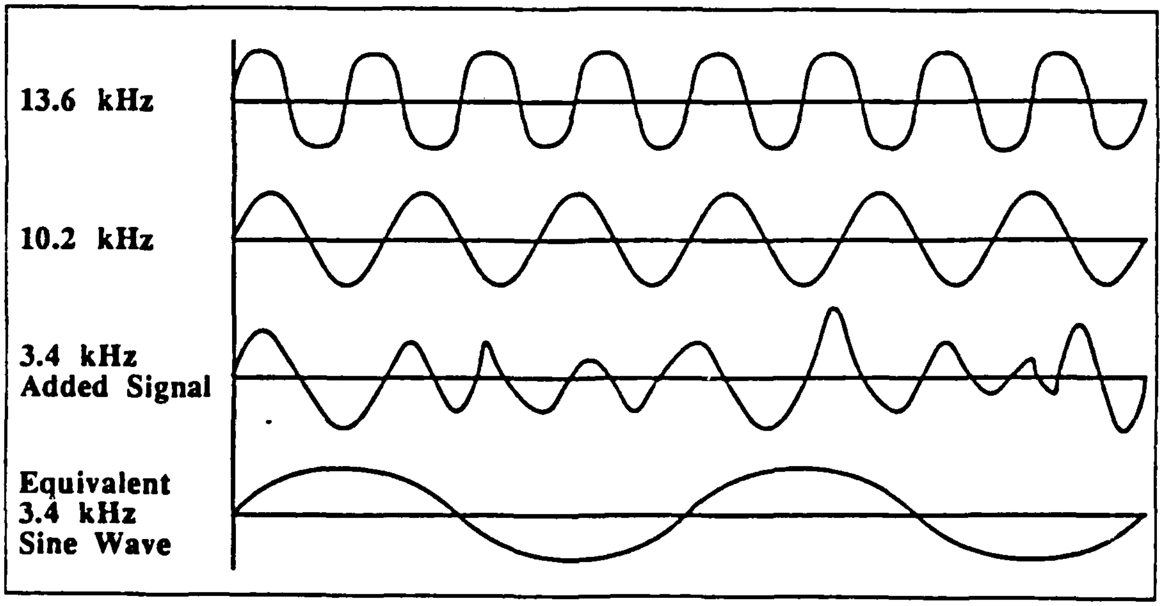

Figure 35. 10.2 and 13.6 kHz Signal Mixing

VLF/IFF can be implemented using any single VLF frequency or any combination of OMEGA frequencies. This example was used to demonstrate VLF/IFF's potential to meet varied user requirements, not to focus on a specific design characteristic.

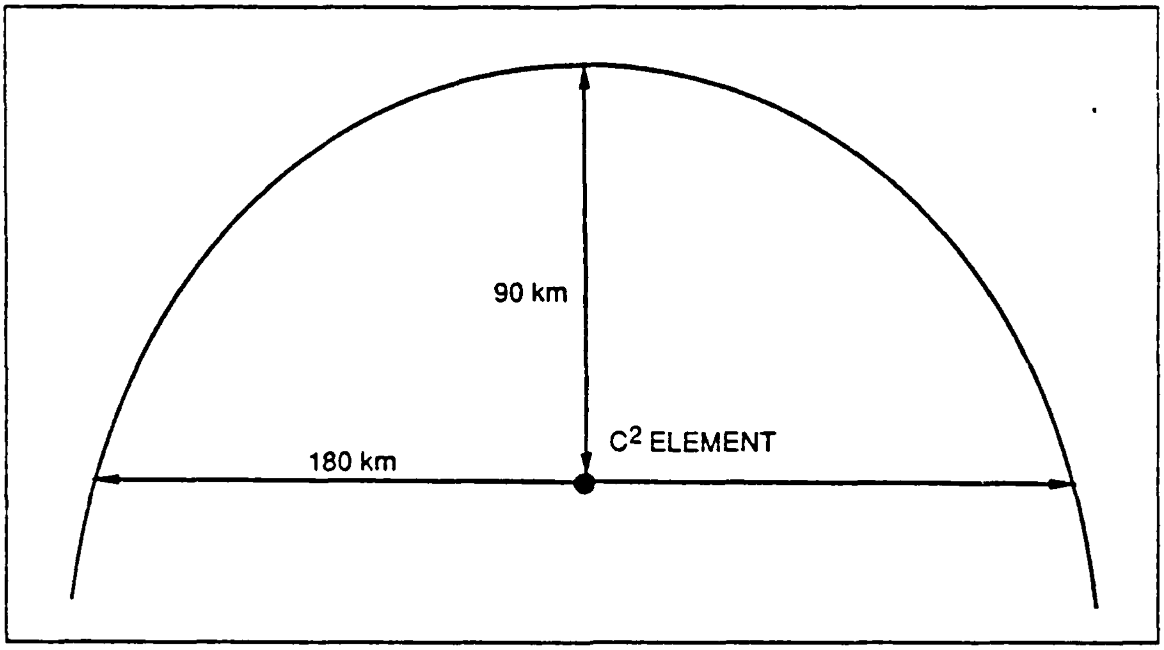

Figure 36. Effective Range of a 3.4 kHz Signal

As currently described, the VLF/IFF system will use OMEGA signals to determine LOP intersections, i.e., positions of maneuver elements, and VLF COMM signals to resolve ambiguities. [Ref. 30:p. 1]

5. VLF Signal Selection

The VLF/IFF system must synchronize with the OMEGA system signal key. This is routinely done in commercial OMEGA receivers using only three to four station signals with the required signal to noise ratio, anywhere in the world. [Ref. 42:p. 8]

Since a given OMEGA frequency occurs only once every ten seconds for a given station, the VLF receiver must synthesize that signal internally to reference it's zero phase crossings for use in determining TOA's over the entire ten second period. This is done in both the maneuver element and command and control element VLF receivers, using a phase locked loop. Rate errors caused by movement of the maneuver element in relation to the C2 element are compensated for through the use of predictive filters, thereby providing accurate, current position information throughout the 10 second period. [Ref. 31:pp. 3.51-3.53]

These noise free, synthesized signals then generate electronic pulses at each zero phase crossing. An example of this is shown in Figure 37 [Ref. 31:Fig. 4.6]. Precision signal generation is ensured by the use of very stable crystal oscillators. VLF/IFF pro-

poses using a crystal oscillator stable to 10^{-8}/day in the maneuver element VLF receiver and a crystal oscillator stable to 10^{-10}/day in the command and control element VLF receiver [Ref. 30:pp. 3.55-3.56]. Use of these highly stable crystal oscillators guarantees short term accuracies (ten seconds in the case of VLF/IFF) on the scale of 10^{-10} and 10^{-12} respectively [Ref. 44:p. 120].

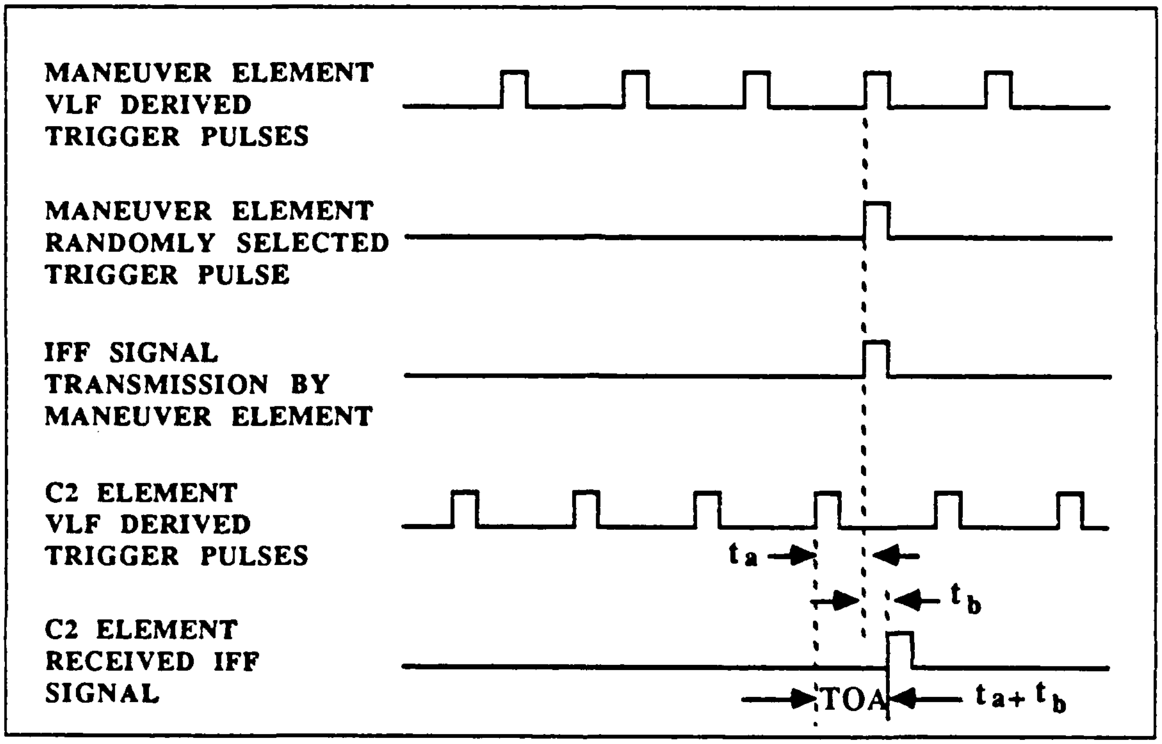

Figure 37. VLF Trigger Pulses

Both the maneuver element and command and control element must be synchronized in terms of which VLF pulses will be referenced over a given period. More precisely, for the system to function properly both the maneuver element and the command and control element must reference the same pulse stream. For example, at some time period T_0 to T_1, both elements could reference the Norway generated pulses. Then, from time period T_1 to T_2 they could both reference the VLF COMM station at Cutler, Maine. It is through this process that each the station's associated TOA's are measured and LOPs defined. [Ref. 31:pp. 3.57-3.63]

A proposed VLF/IFF reference 'key' is shown in Figure 38. This VLF/IFF key uses the eight precisely defined time slots of OMEGA and identifies examples of which pulse stream will be referenced by all system elements during each time slot. This asso-

ciation of specific station pulse streams and the eight time slots is arbitrary and independent of the normal use of the OMEGA key. [Ref. 31:Fig. 3.22]

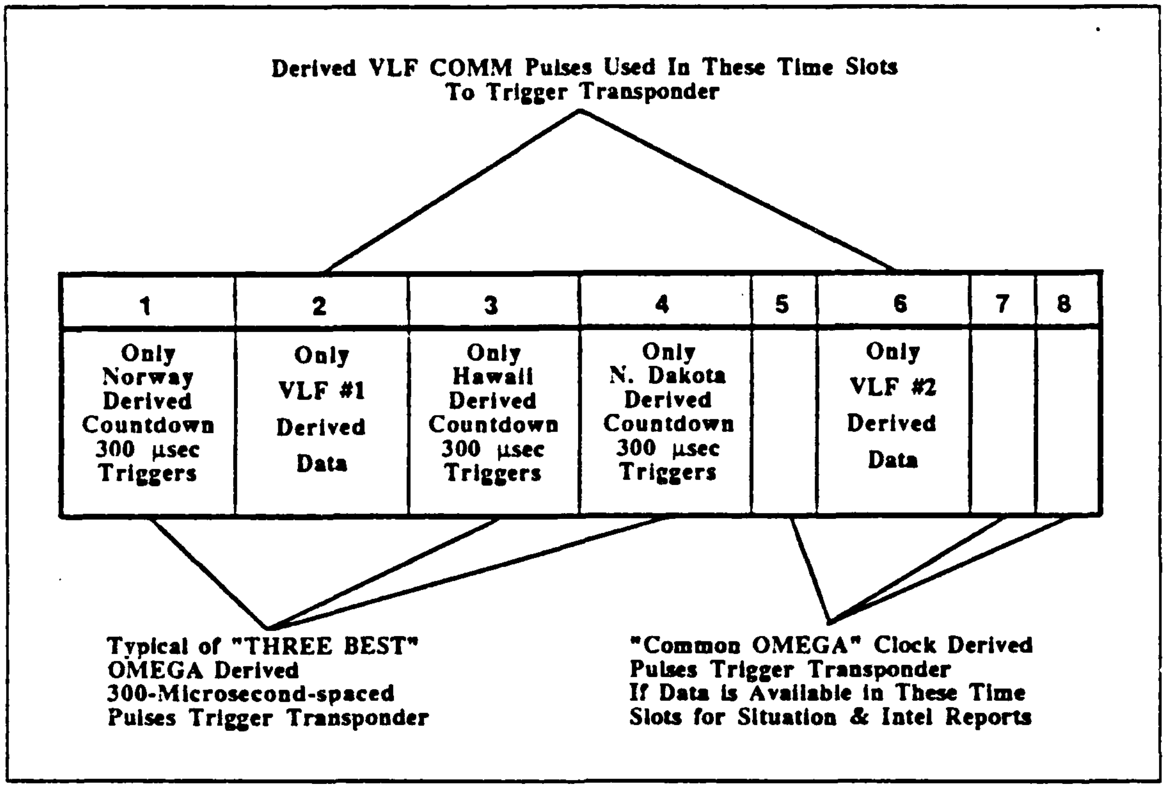

Figure 38. VLF/IFF Key

The eight OMEGA time slots were chosen in this example because they are already precisely defined in time to all VLF/IFF users. This could be specified otherwise if so desired. Since only three to four OMEGA and one to two VLF COMM signals are needed for the system to work, the best available signals are chosen and the rest are 'deselected' to avoid accuracy degradation. This creates open slots in the VLF/IFF 'key' that could be used for transmission of immediate tactical intelligence. [Ref. 31:pp. 3.57-3.63]

6. Random IFF

Using 300 μs listening periods will establish 3,333 time slots per second. This calculation is shown in equation 3.8.

$$\text{Number of Time Slots} = \frac{1\ \text{sec}}{300\mu s} = 3.333 \times 10^3 = 3{,}333 \qquad (3.8)$$

To preclude continuous (i.e., once every 300 μs) radiation by the maneuver element, VLF/IFF proposes that each transponder be triggered ten times per second leaving 3,323 time slots open for other transponder transmissions [Ref. 30:p. 6]. This rate is arbitrary and should be chosen for each maneuver element based on how often a position update is required given the maneuver element's operating characteristics, mission requirements, and the needs of the user community.

To statistically reduce the probability of two maneuver elements transmitting at the same instant, possibly causing their signals to overlap and become 'garbled' at the command and control receiver, the 300 μs pulses used to trigger the transponder are selected randomly using a random number generator. This eliminates a major weakness of the ATCRBS, i.e., synchronous code garbling, and allows for tracking of a high density of maneuver elements in near proximity to each other. [Ref. 31:pp. 3.63-3.65]

A VLF/IFF command and control element using 300 μs listening periods (3,333 time slots/sec) and a reporting rate of 10 signals/sec could simultaneously support more than 300 maneuver elements [Ref. 31:pp. 3.63-3.68]. This calculation is shown in equation 3.9.

$$\text{Number of Platforms} = \frac{3{,}333 \text{ time slots}}{10 \text{ time slots/platform}} = 333 \qquad (3.9)$$

Selecting a transmission rate of ten times per second also demonstrates that if four or five transponder transmissions are by chance or design, garbled or jammed, there are still five or six good signals to measure several reliable, accurate TOA's and determine an associated LOP. Only three TOA's are required to perform this operation. The extra seven or so provide a measure of redundancy, improved accuracy and robustness. [Ref. 31:pp. 3.64-3.65]

An interesting fact concerning the only 'active' component of the VLF/IFF system, i.e., the transponder, is that since each burst occurs approximately once every tenth of a second and lasts only 21 μs, the duty cycle of the system is only 0.00021. This calculation is shown in equation 3.10. [Ref. 35:pp. 70-71]

$$d_{VLF/IFF} = \frac{\tau}{T} = \frac{21 \mu s}{\left(\frac{1 \times 10^{-5} \mu s}{10} \right)} = 0.00021 \qquad (3.10)$$

The transponder is normally limited to 1200 transmissions per second [Ref. 34:p. 38.12]. This equates to a duty cycle of 0.0252. The VLF/IFF workload

placed on the transponder at ten replies per second reduces this number to 0.02499. This is really an insignificant reduction. However, this small number is significant in that it shows VLF/IFF does not detract from the transponder's primary mission of providing ATC/AD information. These calculations are shown in equations 3.11 and 3.12.

$$d_{IFF} = \frac{21\mu s}{\left(\frac{1 \times 10^6 \mu s}{1200}\right)} = 0.0252 \tag{3.11}$$

$$d_{IFF} - d_{VLF/IFF} = 0.0252 - 0.00021 = 0.02499 \tag{3.12}$$

Random triggering and 21 μs bursts provide an additional measure of security against ECM, intelligence collection and targeting by enemy forces. Operation of the transponders in Mode 4 would provide encryption of identification and tactical information. [Ref. 33:pp. 150-152]

7. Autocorrelation

The technique used to ensure correct maneuver element identification and TOA matching is called autocorrelation. The 12 IFF pulses must agree, reply, to reply, to reply. If even 2 of the 10 replies fully correlate there is only a one in $(4{,}096)^2$ or 16.8 million chance that an error of this type will occur using this VLF/IFF coding scheme. [Ref. 31:pp. 3.44-3.47]

Autocorrelation is a common technique incorporated in current IFF/ATCRBS equipment. This technique is used every day to separate and track thousands of aircraft in ATC/AD operations worldwide. [Ref. 34:pp. 38.2-38.16]

8. IFF Tactical Intelligence Link

VLF/IFF exploits a unique potential of the transponder. The transponder has a 4,096 code word capacity to reply to each mode of interrogation. If the 'X pulse' is used, this capacity doubles to 8,192 possible code words per mode. VLF/IFF proposes reserving one of the interrogation modes for transmission of perishable and critical tactical intelligence from maneuver elements to command and control elements. An example of such a transmission is depicted in Figure 39. [Ref. 31:pp. 3.23-3.29]

This could be done in a manner similar to the current three letter operation codes published in the Communications Electronic Operating Instructions (CEOI). Typical input data to standard battlefield reports, i.e., situation reports (SITREPS) or nuclear, biological, or chemical reports (NBC-1, NBC-2, etc.), could be generated using a keyboard or a voice actuated encoding device. Both of these items could be provided

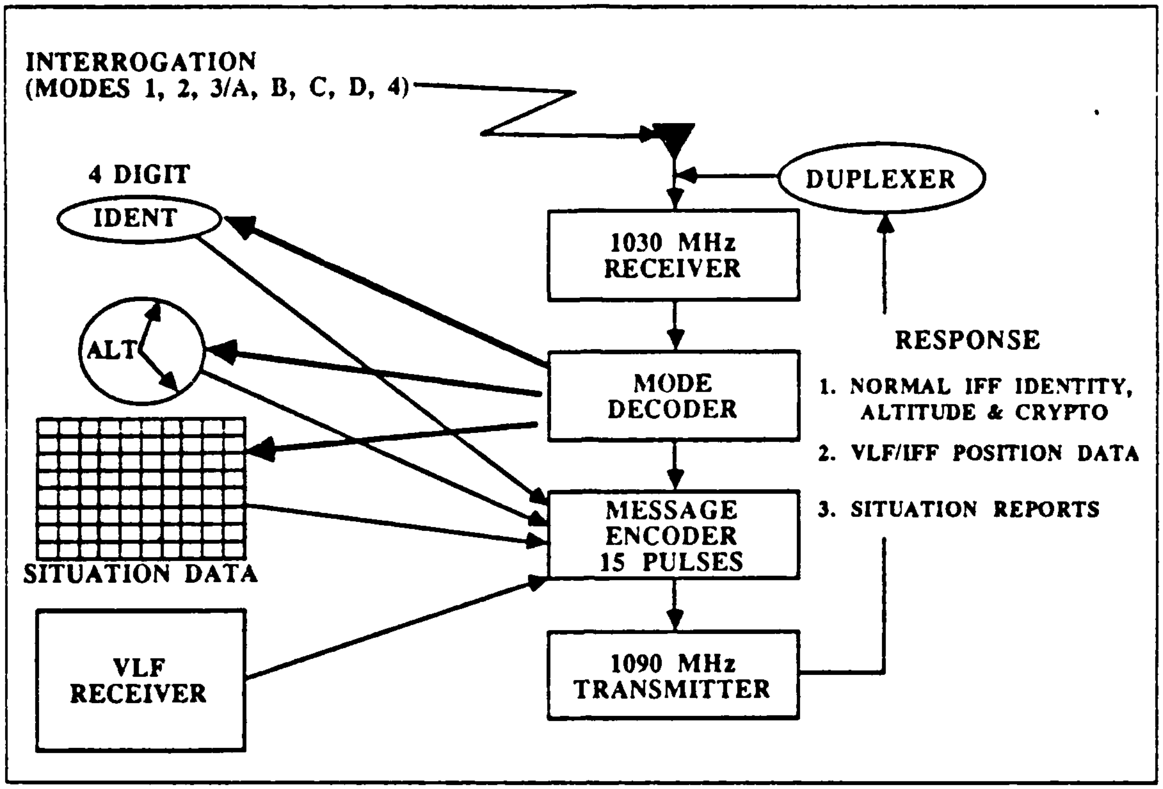

Figure 39. Tactical Data Link

with 'off the shelf' technologies. An example of code words for a given day and time period might be as shown in Table 7 on page 108.

VLF/IFF would also provide a potential link for passing combat information generated by other automated information reporting systems, such as the Inter-Vehicular Information Systems (IVIS) [Ref. 17].

Since the command and control center knows the identity and position of the friendly maneuver element, it could easily use the code word information to determine the enemy's activity and relative position.

9. Error Budget

To determine if VLF/IFF will meet the 100 meter accuracy requirement stated in Chapter Two, potential sources of error must be identified. Each source of error contributes to an overall error budget for the system. An error may have either a positive or negative value. A normal distribution of errors is assumed.

The sources of error are typical of position reporting systems. The values attributed to each source of error are conservative estimates based on the results of a

Table 7. VLF/IFF TACTICAL INTELLIGENCE CODE

CODE WORD:	MEANING:
310	Tank(s)
320	Armored Personnel Carrier(s)
330	5 Ton Truck(s)
410	At My Location
420	From My Location
510	One
520	Two
530	Three
610	Kilometer(s)
620	Miles(s)
710	North
720	South
730	East
740	West

The message text: "310, 420, 510, 610, 730."
The message conveyed: "Tanks, from my location, one kilometer, east."

similar initiative recently conducted in England and contract work done for the Jet Propulsion Laboratory. The potential sources of error for VLF/IFF and an estimate of their associated values are shown in Table 8 on page 109 and Table 9 on page 110. [Ref. 31:pp. 5.1-5.24]

Table 10 on page 111 and Table 11 on page 112 show the root-mean-square calculations or S values for two sets of errors. The first set consists of those error values already presented. The second set represents a 25% increase in all the first set values. This is done to examine the significance and potential impact of any gross underestimate of error values on the overall determination of system accuracy. The magnitude of this increase in values is highly unlikely and is used only to highlight the minor impact a significant change to any number of error values would contribute to the final S value. [Ref. 45:p. 155]

The S value is a measure of system accuracy. It is associated with a statistical measure of confidence. Leave it to say for the purposes of this discussion that a 1σ value about the mean relates to a 67% confidence level, 2σ to 95% and 3σ to 99%.

Table 8. APPROXIMATION OF VLF/IFF ERRORS

ERROR SOURCE:	ABSOLUTE DISTANCE:
1. Crystal drift at maneuver element and crystal drift at the C2 node.	5 meters;
2. Angle of Arrival of the VLF signal and any distortion of this angle of arrival or bending of it due to local conditions.	25 meters after corrections by use of well known angle of arrival technology.
3. Signal to noise ratio on the strongest OMEGA signal.	20 meters;
4. Signal to noise ratio on the second strongest OMEGA signal.	30 meters;
5. Signal to noise ratio on the third strongest OMEGA signal.	0 meters; The third signal is used for eliminating the false crossing.
6. Signal to noise ratio on the strongest VLF COMM signal.	20 meters;
7. Platform motion and the ability to use rate aided tracking such as Kalman to obtain predictive and real time positions.	50 meters;
8. Platform errors due to changes in heading of the platform.	Momentarily 75 meters until rate aided tracking has locked to the new straight track.
9. Any variations across 100 km area in propagation velocity of the VLF signal due to local geodetic conditions.	20 meters after local corrections
10. Local mineral deposits or highly concentrated minerals in the area.	30 meters across a 100 km battlefield.
11. Phase locked loop accuracy.	40 meters;

Table 9. APPROXIMATION OF VLF/IFF ERRORS (CONTINUED)

ERROR SOURCE:	ABSOLUTE DISTANCE:
12. Geometric Dilution of Positions (GDOP).	40 meters;
13. Coordinate conversions (such as elliptical, parabolic, and rectilinear or polar coordinates).	30 meters;
14. Digital computer quantizing errors.	5 meters;
15. Deselection options to void out VLF signals that can create errors such as noisy ones or those perturbed by some local condition on the path from the VLF/IFF site to the far distant OMEGA in that direction.	Reduction of position errors by 30% if the errors are created by a noisy signal that can be deselected in the process. Therefore, this is an improvement of of accuracy.
16. Display processor errors.	30 meters;
17. Platform movement Kalman predictive errors to create a real time continuous position. This is known as "rate aided" tracking in the VLF receiver design and is an essential part of all OMEGA receivers.	20 meters;
18. C2 node Kalman predictive errors with regard to real time using rate aided tracking on the same targets even though the C2 node is a fixed position to further use modern computer processing as Kalman predictive vector to increase the accuracy of the display.	10 meters;

Figure 40 shows the expected VLF/IFF system accuracies, derived from the two σ values, related to the three levels of confidence introduced above. This figure shows that for the first set of error values, VLF/IFF would, with 99% confidence, generate

Table 10. RMS CALCULATIONS -- SET ONE

ERROR #:	$(X_i - \overline{X})$	$(X_i - \overline{X})^2$
1.	5 meters	25 meters
2.	25 meters	625 meters
3.	20 meters	400 meters
4.	30 meters	900 meters
5.	0 meters	0 meters
6.	20 meters	400 meters
7.	50 meters	2500 meters
8.	75 meters	5600 meters
9.	20 meters	400 meters
10.	30 meters	900 meters
11.	40 meters	1600 meters
12.	40 meters	1600 meters
13.	30 meters	900 meters
14.	5 meters	25 meters
15.	0 meters	0 meters
16.	30 meters	900 meters
17.	20 meters	400 meters
18.	10 meters	100 meters

****

$$S = \sqrt{\frac{\Sigma(X_i - \overline{X})^2}{N-1}} \tag{3.13}$$

****

$\Sigma(X_i - \overline{X})^2$ ....17350 meters

$\frac{\Sigma(X_i - \overline{X})^2}{N-1}$ ....1020.59 meters

$\sqrt{\frac{\Sigma(X_i - \overline{X})^2}{N-1}}$ ....31.90 meters

position accuracies on the order of 96 meters. This is within the 100 meter requirement specified in Chapter Two.

Also shown is the fact that a substantial change in all error values, as demonstrated with the second set, still produces position accuracies, with 95% confidence, on

Table 11. RMS CALCULATIONS -- SET TWO

ERROR #:	$(X_i - \overline{X})$	$(X_i - \overline{X})^2$
1.	6.25 meters	39.06 meters
2.	31.25 meters	976.56 meters
3.	25 meters	625 meters
4.	37.5 meters	1406.25 meters
5.	0 meters	0 meters
6.	25 meters	625 meters
7.	62.5 meters	3906.25 meters
8.	93.75 meters	8789.06 meters
9.	25 meters	625 meters
10.	37.5 meters	1406.25 meters
11.	50 meters	2500 meters
12.	50 meters	2500 meters
13.	37.5 meters	1406.25 meters
14	6.25 meters	39.06 meters
15.	0 meters	0 meters
16.	37.5 meters	1406.25 meters
17.	25 meters	625 meters
18.	12.5 meters	156.25 meters

****

$$S = \sqrt{\frac{\Sigma(X_i - \overline{X})^2}{N - 1}} \tag{3.14}$$

****

$\Sigma(X_i - \overline{X})^2$ ....27031.24 meters

$\frac{\Sigma(X_i - \overline{X})^2}{N - 1}$ ....1590.07 meters

$\sqrt{\frac{\Sigma(X_i - \overline{X})^2}{N - 1}}$ ....39.88 meters

the order of 80 meters and, with 99% confidence, on the order of 120 meters. Given that a 25% underestimate in all error values is unlikely, this drill serves primarily to illustrate that VLF/IFF has a high probability of generating accuracies on the order of the 100 meters required.

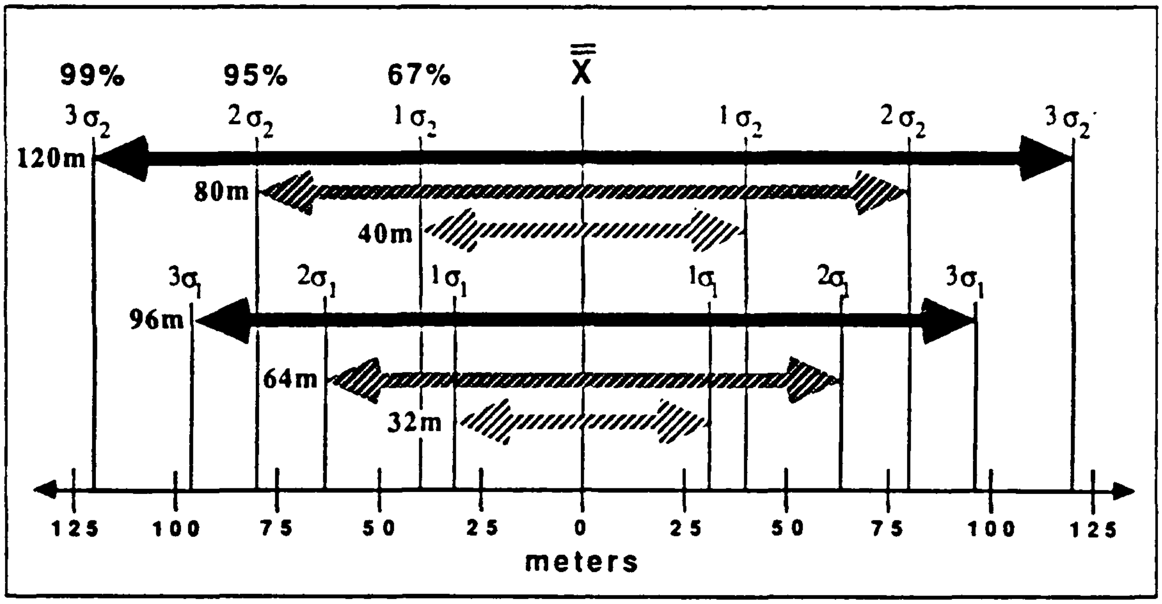

Figure 40. Root Mean Square Value Distributions

The error values for numbers 7, 8, 11, 17 and 18 are all related to rate changes essential for Kalman tracking of dynamic maneuver elements. These error values are known with a lesser degree of certainty than the others and are therefore the most likely of the error values to change. The potential accuracies that these σ values represent warrants their verification through a technical process.

For C2 display purposes, precision position accuracies on the order of 1 to 10 meters may be unnecessary. Figure 41 shows a typical C2 display screen with 1,280 by 1,024 graphics. This display contains 1,310,720 pixels. If the scale represented on the display were 8 nautical miles or 15,120 meters on each side, the display area would be 229 million square meters (m^2). This in turn relates to a display accuracy of approximately 175 m^2/pixel. This means that each pixel, which is indistinguishable to the human eye, represents 175 m^2 on the ground. Any display generated representation of a maneuver or C2 element would require a screen area of at least 20 x 20 pixels or cover a ground equivalent area equal to 70,000 m^2. Thus, to demand position accuracies on the order of 1 to 10 meters for C2 display purposes would be extravagant.

F. FUNCTIONAL DESCRIPTION

1. Overview

Figure 42 depicts a relational diagram of the VLF/IFF system components [Ref. 30:Fig. 10]. This figure shows two typical VLF wave fronts, generated by either

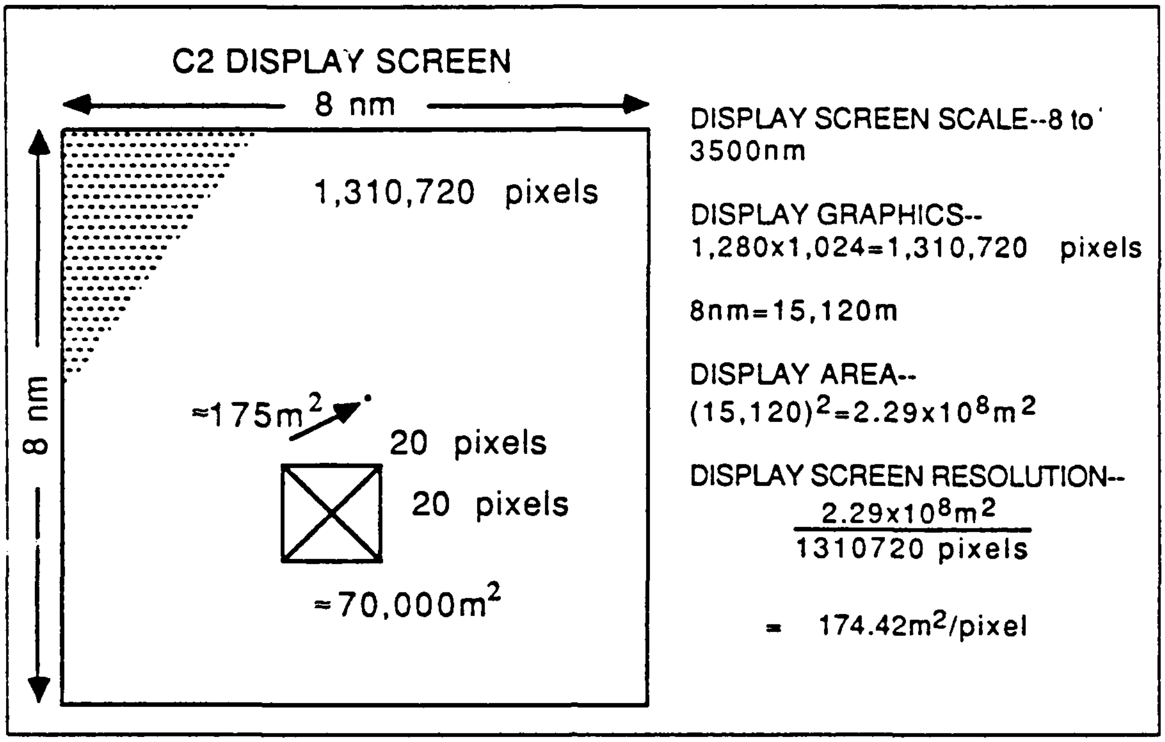

Figure 41. C2 Display Screen Calculations

VLF COMM or OMEGA stations, crossing a localized battlefield. These signals are used by the command and control element for clocking purposes. These same wave fronts are used to trigger the maneuver element transponder. The UHF transponder signal is transmitted to the command and control element where it is used to determine identity and to calculate the relative position of the maneuver element for display.

The VLF stations are typically 1,000 to 8,000 miles distant from the maneuver element and the command and control elements. The maneuver element and the command and control element are typically separated on the order of less than 45 kilometers.

The VLF signals are ground wave signals that are available at all altitudes, everywhere on the battlefield, regardless of terrain. The UHF signal requires only one line of sight between the maneuver element and any command and control element. With VLF/IFF, the maneuver element is not tied to any one command and control element. In fact, a maneuver element will input to the VLF/IFF system and interact with any number of C2 elements to which it has line of sight. This feature highlights VLF/IFF's distributed nature. [Ref. 30:p. 13]

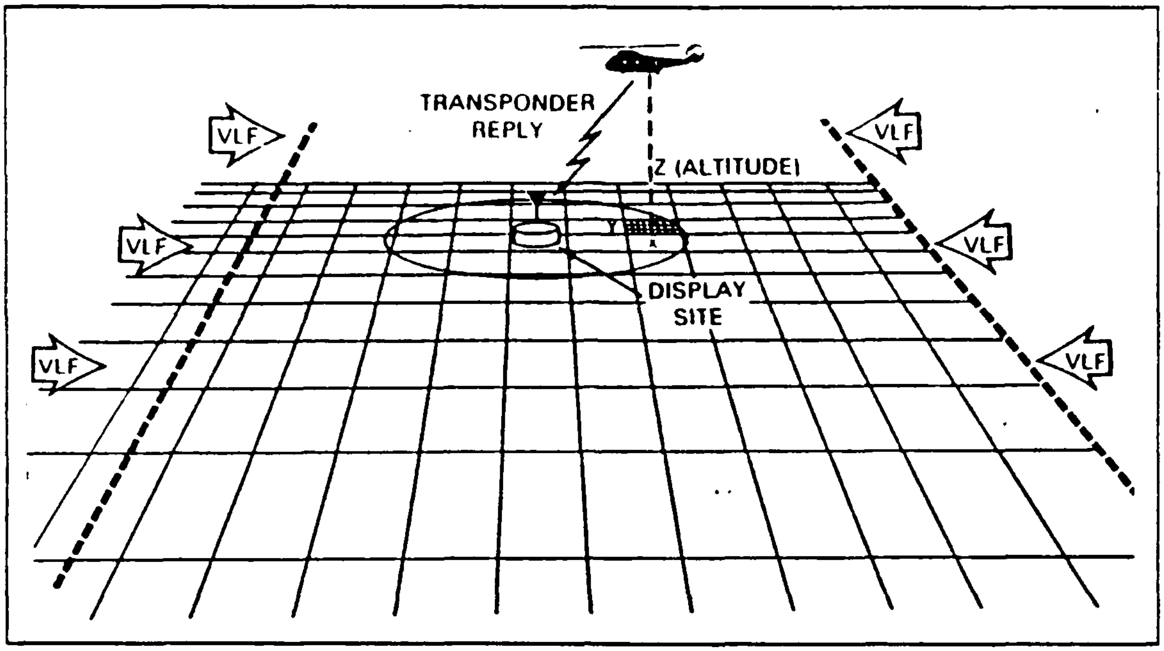

Figure 42. VLF/IFF System Components

In the VLF/IFF system, the VLF signal is used for time synchronization of all battlefield players. The UHF transponder signal is used in a traditional manner for reporting identity, altitude and other operational data. [Ref. 30:pp. 12-13]

2. System Operation

This discussion will not evaluate the VLF signal generation or the operation of the OMEGA and VLF COMM systems. However, it will discuss how the VLF signal is used in the VLF/IFF system. This discussion will focus primarily on the maneuver element and command and control elements, their components, and how the system will generate and display the friendly battlefield situation.

a. Maneuver Element

The maneuver element contains those components shown in Figure 43. The VLF/IFF components consist of a VLF receiver and a UHF transponder. [Ref. 30:Fig. 4.7]

(1) Signal Receipt. Commercial VLF receivers typically have a four frequency capacity. Three of the frequencies are tuned to the OMEGA navigation frequencies, the fourth scans the VLF COMM frequencies [Ref. 31:pp. 4.7-4.10]. See Figure 44 for an illustration of this concept [Ref. 31:Fig. 4.8].

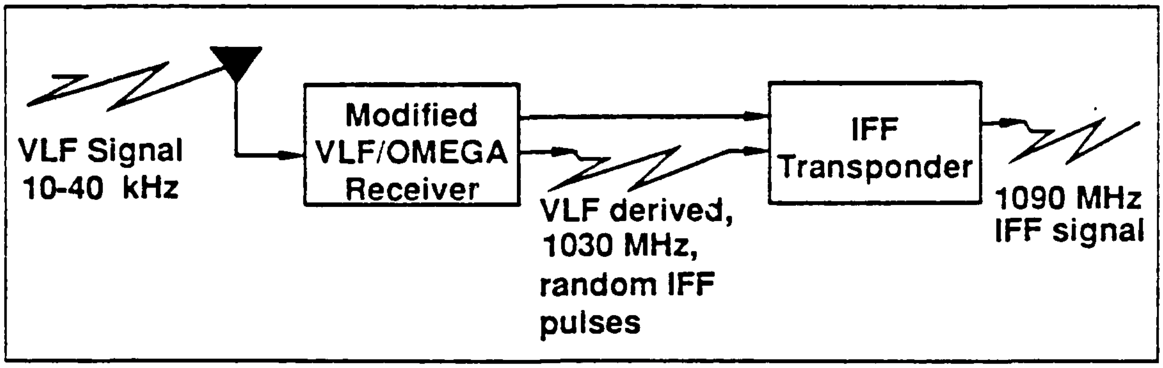

Figure 43. Maneuver Element Components

(a) Antenna Requirements— Receipt of the VLF signal requires an appropriate antenna. There are currently three types of antennae suitable for this purpose. Two whip antennae will be needed for ground maneuver elements; one for the VLF signal and one for the UHF signal. An E-field or H-field VLF antenna is required for aircraft. However, an H-field antenna is preferred due to it's relative immunity to P-static disturbances. The antenna for the transponder is already mounted on the aircraft. [Ref. 31:p. 4.10]

(b) VLF Frequency Tuner— The VLF/OMEGA tuner has the ability to autonomously recognize the eight OMEGA time slot transmissions and synchronize to the OMEGA key. The tuner identifies the signal's station and frequency to the channel selector. [Ref. 31:p. 4.8]

(c) Channel Selector— The channel selector determines the best three or four VLF signals available based on signal to noise ratio and angle of arrival. It then deselects the other stations. The channel selector specifies the channels (station and frequencies) it wishes to receive to the tuner. In any one OMEGA time slot, the receiver may spend time listening to the 10.2 kHz signal from one station and the 13.6 kHz signal from a different station. [Ref. 31:p. 4.8]

(2) Signal Processing. Signal processing at the maneuver element involves VLF signal synthesis, VLF signal prediction, and timing pulse generation. See Figure 44. [Ref. 31:Fig. 4.8]

(a) Stable Frequency Pattern Synthesizers— The selected channel signals are then run through a phase locked loop to synthesize a like VLF signal in frequency and phase. This synthesis is done using a 10^{-8}/day stable crystal. This phase locked loop process is performed once every ten seconds for each station in synchroni-

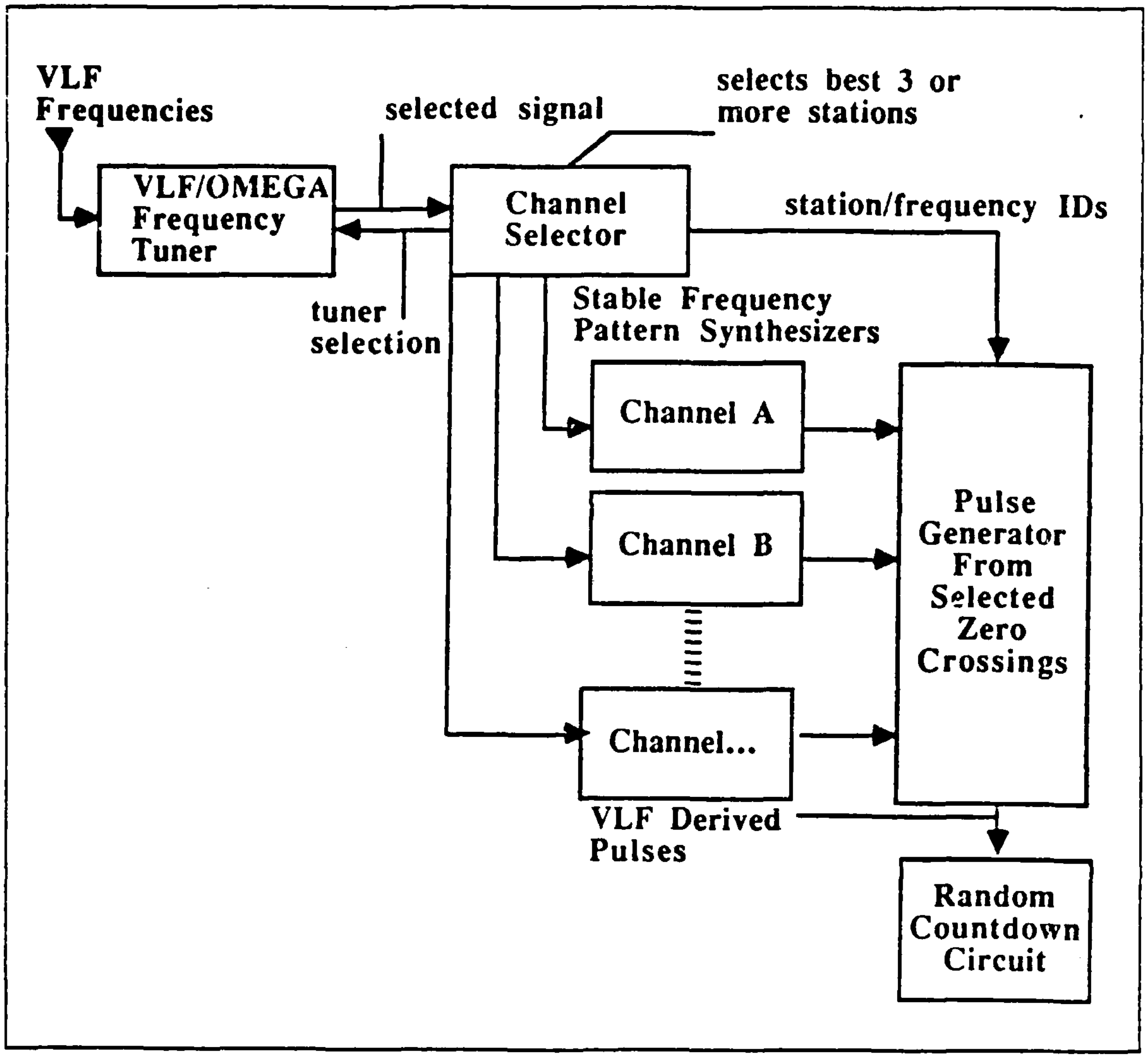

Figure 44. Maneuver Element VLF Signal Receipt/Processing

zation with the OMEGA time slot key. These synthesized signals are then stored over the ten second period. The zero phase crossing of these synthesized signals are used for timing reference points by the pulse generator. [Ref. 31:p. 4.9]

(b) Signal Prediction— Since the synthesized VLF signals are updated only once every ten seconds, it is necessary to account for phase shift and hence changes in zero phase crossings that result from movement of the maneuver element relative to the command and control element. [Ref. 31:p. 3.51]

The VLF receiver uses Kalman filtering to predict changes in the VLF signal zero crossings due to movement of the maneuver element. These linear

predictive techniques minimize the potential for error in position determination during the nine seconds of 'off' time for a given frequency from each OMEGA station. [Ref. 31:p. 3.51]

Predictions made by Kalman filtering are based on the maneuver element heading averaged over a given period of time. In VLF/IFF, sudden changes in heading are fed into the Kalman filter and corrections are applied immediately. The filter then settles into an averaging pattern again after several samples. [Ref. 31:p. 3.51]

(c) Pulse Generator— The pulse generator uses zero phase crossings of the synthesized signals to generate pulses. These pulses can be generated using single frequency zero phase crossings or a combination of zero phase crossings, i.e., 10.2 kHz and 13.6 kHz. [Ref. 31:p. 4.9]

(3) Signal Transmission.

(a) Random Countdown Circuit— The random countdown circuit randomly selects pulses generated by the pulse generator to trigger the IFF interrogator circuit. This circuit ensures that only about ten of these pulses are selected per second. The pulse stream referenced at any given time is specified in the user defined VLF/IFF key. [Ref. 31:p. 4.9]

(b) VLF Transponder Trigger— The VLF transponder could be triggered by generating a low power (5 mW) IFF interrogating signal at 1030 MHz across the skin of the maneuver element. This signal is not strong enough to influence other nearby maneuver element transponders. This 1030 MHz signal allows the transponder to perform in it's designed manner, i.e., no modifications are necessary to the transponder. Alternatively, a direct wire connection to the transponder can be used. The 1030 MHz signal format can generate any of several modes, thereby causing the transponder to supply identification, altitude, or battlefield information. [Ref. 31:p. 4.10]

(c) IFF Transponder— The IFF transponder, upon receipt of the 1030 MHz interrogation signal will deselect the IFF antenna, decode the interrogation, encode the appropriate 21 μs, 1090 MHz response and then apply the 500 W signal to the omni-directional antenna for transmission to the command and control element. The block diagram of the IFF transponder is shown in Figure 45. [Ref. 31:p. 4.10]

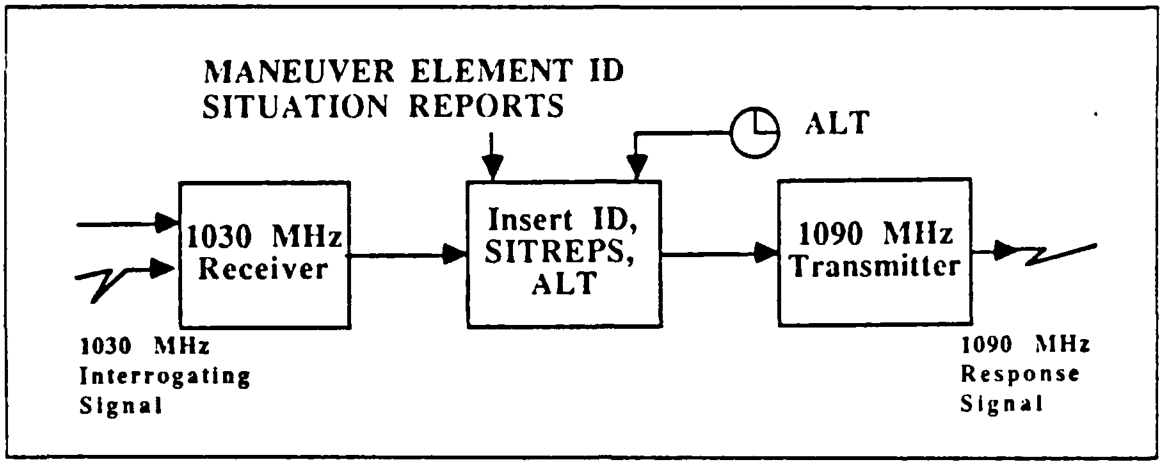

Figure 45. Maneuver Element IFF Signal Transmission

b. Command and Control Element

The command and control element consists of a VLF receiver, an IFF receiver/processor, a position coordinate processor, a display driver, and a display. The breakdown of these components is illustrated in Figure 46. [Ref. 31:Fig. 4.10]

(1) Signal Receipt.

(a) VLF Receiver— See Figure 47 for the block diagram of the VLF receiver [Ref. 31:Fig. 4.11].

- Antenna Requirements: The VLF receiver will require a whip antenna, similar to that used by the maneuver element.
- VLF Frequency Tuner: This component functions in the same manner as the maneuver element tuner.
- Channel Selector: The channel selector functions in a manner similar to the channel selector of the maneuver element. The main difference being that the command and control element must be able to detect and select the best three signals in all eight OMEGA time slots over the ten second period. This allows the system to adjust for maneuver elements selecting different OMEGA stations. VLF COMM stations are purposely assigned to certain time slots in the OMEGA period. [Ref. 31:pp. 4.11-4.12]

(b) IFF Receiver/Processor— The block diagram of the IFF receiver/processor is illustrated in Figure 48 [Ref. 31:Fig. 4.12].

- Antenna Requirement: The IFF receiver/processor will require an elevated or whip antenna.
- Receiver/Processor: The IFF receiver/processor borrows from existing SSR technology to receive the 1090 MHz IFF encoded signal from the maneuver element.

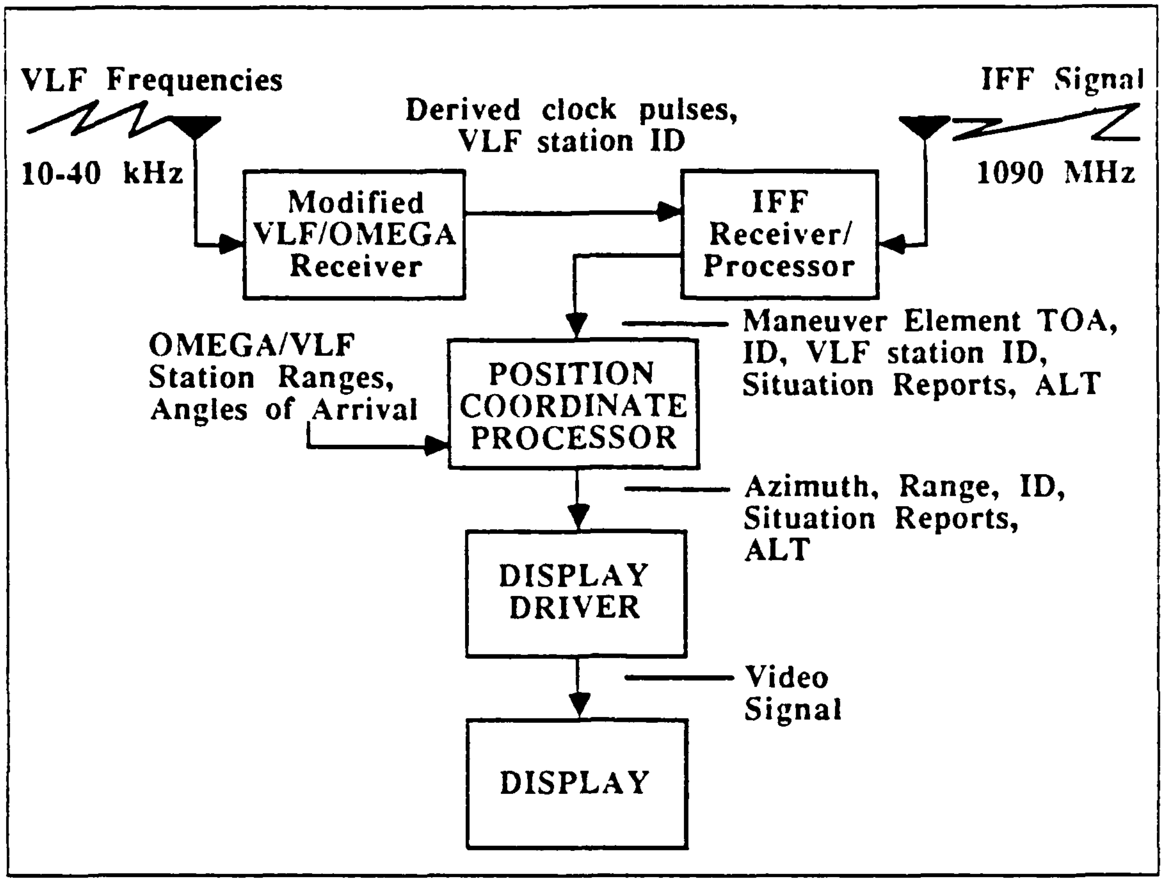

Figure 46. Command and Control Element Components

(2) Signal Processing. Signal processing at the command and control element involves VLF signal synthesis, timing pulse generation, and position determination [Ref. 31:p. 4.11].

(a) Signal Synthesis— VLF signal synthesis occurs in the same manner as at the maneuver element receiver. The one exception being that the command and control element must synthesize all eight OMEGA signals and those VLF COMM signals that it can receive. The receiver phase locked loop uses a crystal oscillator stable to 10^{-10}/day. [Ref. 31:pp. 4.11-4.12]

(b) Pulse Generation— The zero phase crossings of the synthesized VLF signals are then used to generate timing pulses. These pulses are used to define listening periods for the IFF processor. In the VLF/IFF proposal, the 10.2 and 13.6 kHz signals are combined to generate a 3.4 kHz signal. The zero phase crossings of this signal occur every 300 μs, so timing pulses occur in this example every 300 μs. The pulse

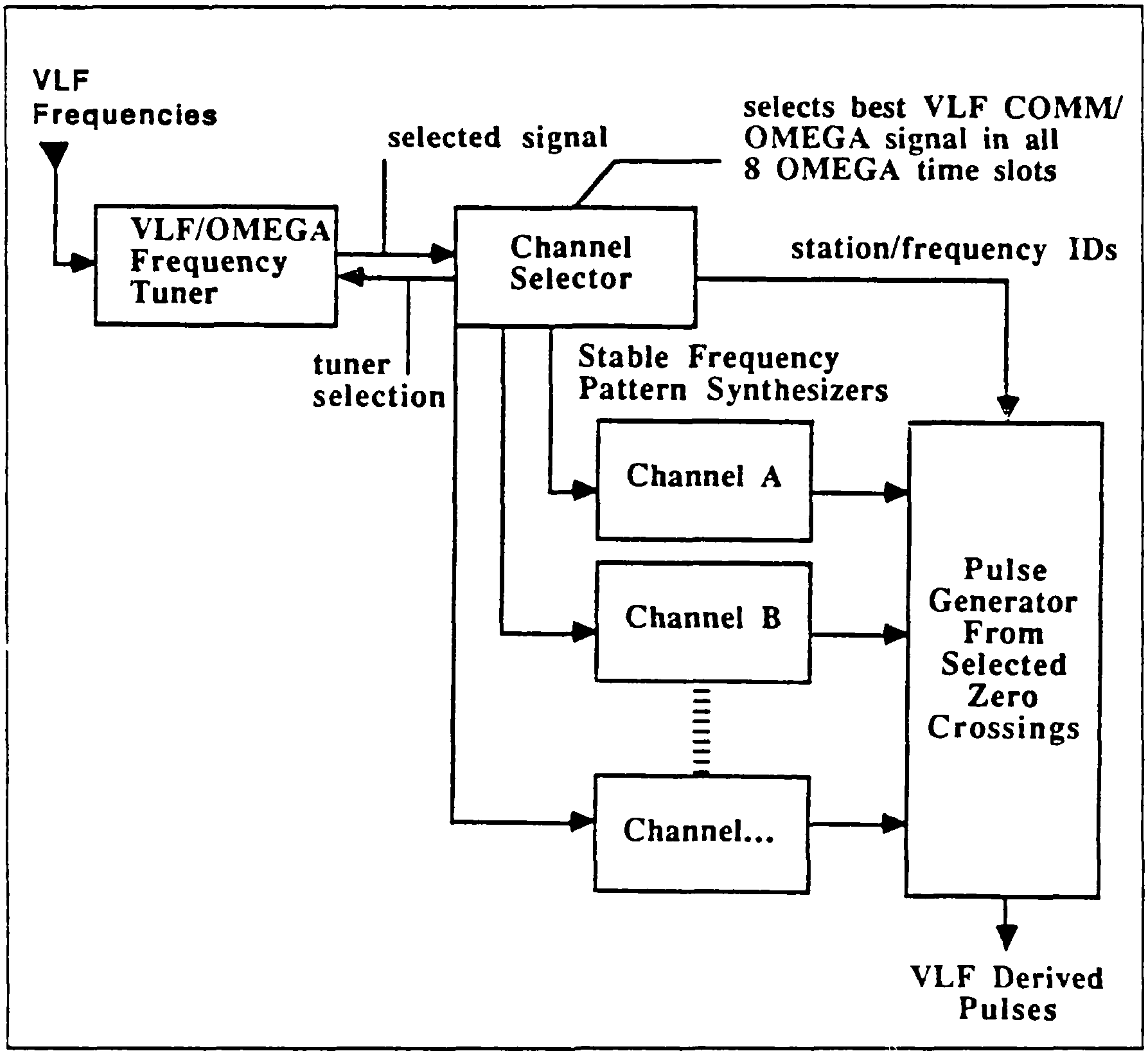

Figure 47. C2 Element VLF Signal Receipt/Processing

stream passed to the IFF Receiver/Processor at any given time is that specified in the user defined VLF/IFF key. [Ref. 31:p. 4.12]

(c) Position Determination— The IFF signal processor uses the timing pulse stream from the VLF receiver and the decoded IFF signal from the maneuver element to determine TOA information. This TOA information, linked with the maneuver element identity, altitude, and any tactical information is then autocorrelated by maneuver element identity. It is through this process of autocorrelation that garbled transmissions and positional ambiguities caused by receipt of ATC/AD radar generated responses are eliminated. [Ref. 31:pp. 4.13-4.14]

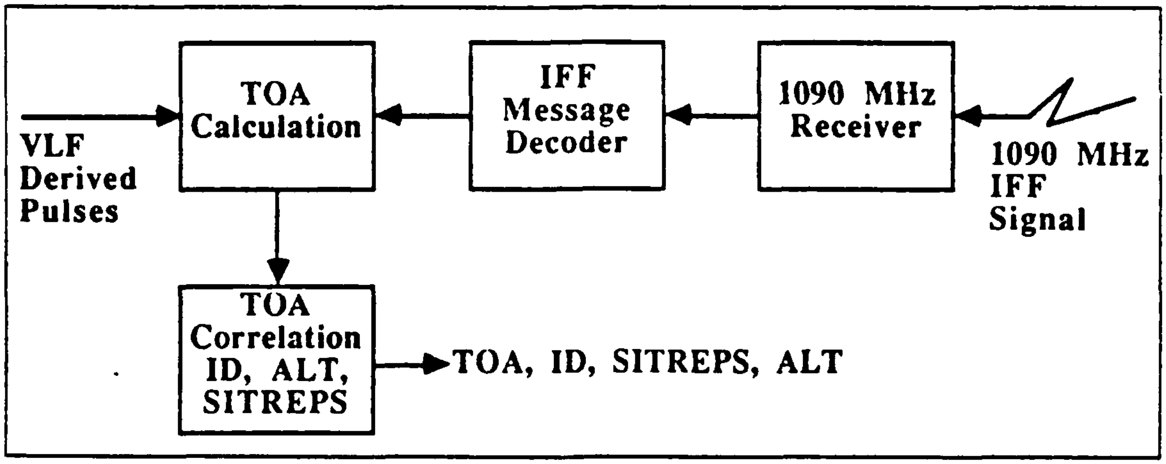

Figure 48. C2 Element IFF Signal Receipt/Processing

Only three TOAs are necessary for the system to function properly. The ten IFF responses generated each second by the maneuver element can be degraded by as much as 70% and the system should still function.

Figure 49 shows the position processor data flow [Ref. 31:Fig. 4.13]. The position coordinate processor translates TOA information into positional data. This is done in polar coordinate format and is then passed to the display subsystem for tracking and display. This processing involves a series of data manipulations and temporary storage of intermediate data values. Throughout this process the identification tag is locked to the position information. It is an integral part of the command and control data. More specifically:

- The input to the data flow diagram includes a paired TOA value and maneuver element identification, per OMEGA time slot that has been averaged from multiple TOAs measured in a single time slot. These TOAs are stored in the appropriate time slot of the table.
- The calculation sequencer matches the appropriate TOA pairs based on a ranking of received signal strength. These TOA pairs are used along with information on signal angle of arrival from the VLF stations and distance to the stations to compute LOPs and from that the two possible positions.
- These possible positions are then stored in rank order. The first position pair is assumed to hold the true position and the rest are used for ambiguity resolution. Possible positions are fed into the ambiguity resolver. Other rank ordered positions are used to determine the true position.
- Azimuth, range, and identity are then passed to the display driver. [Ref. 31:pp. 4.13-4.14]

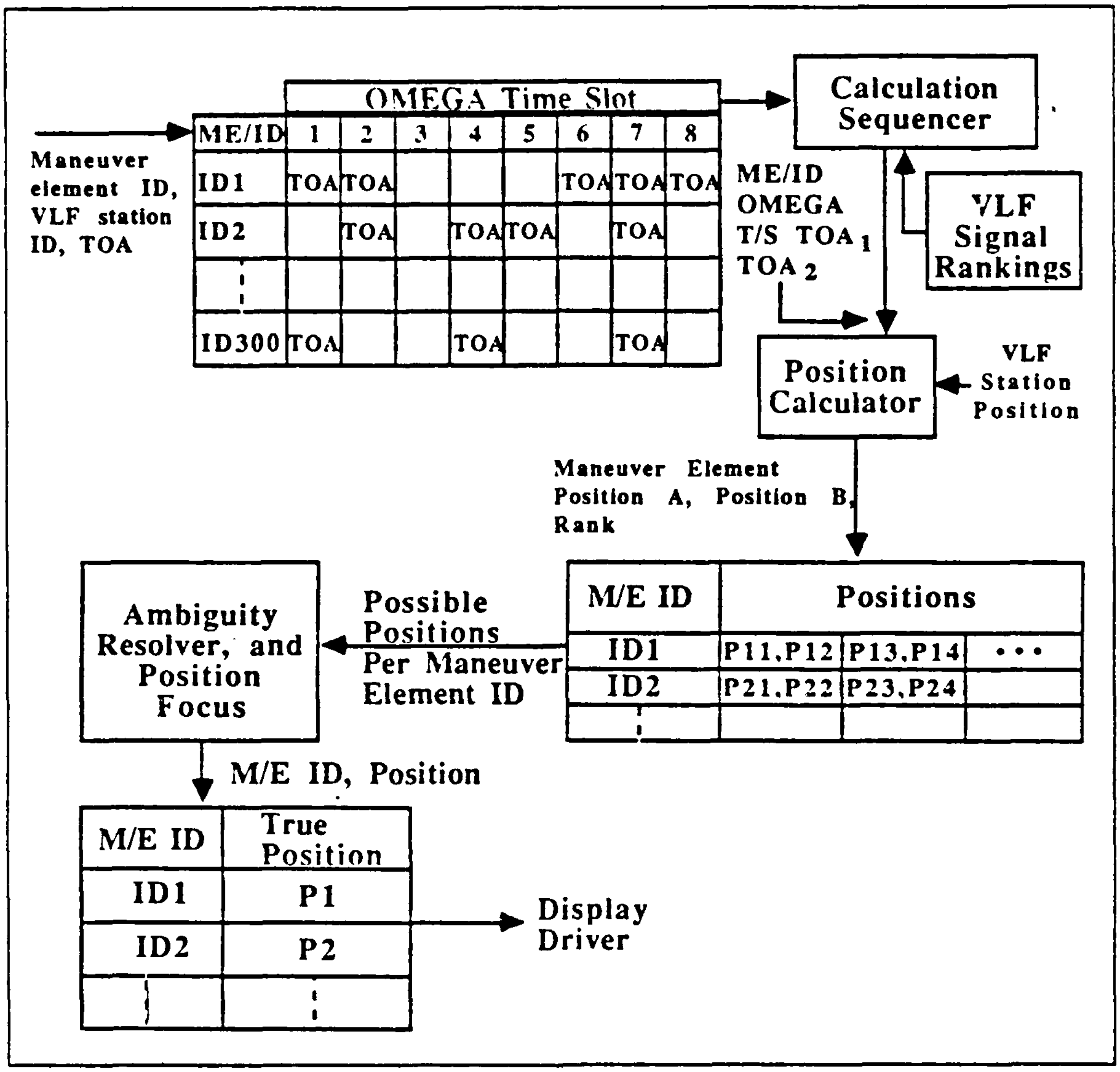

Figure 49. C2 Element Position Processor Data Flow

(d) Display Signal Generation— The position fix passed from the coordinate processor is then processed by the display driver. Within the display driver, a Kalman filter is used to predict position updates thereby ensuring accurate data over the ten second OMEGA cycle. The display driver simply converts the identification, position and intelligence data to a video signal for input to the ATCCS database and for presentation on the ATCCS display screen. [Ref. 31:pp. 3.51-3.53]

(3) Video Signal Display. VLF/IFF creates a real time, friendly disposition data base which can be accessed in numerous ways by the ATCCS database

management system. The way in which the data base is accessed and the way friendly disposition is displayed will depend on the functional area user's needs and his echelon in the command and control system hierarchy.

The position information is displayed relative to the command and control element. This can be done to whatever scale is required by each echelon, from corps to battalion level. The display can be in UTM grid or polar coordinate reference. [Ref. 31:p. 4.15]

The system will support any type of operation from air traffic control, with individual maneuver element tracking and instantaneous update, to large scale tactical operations, where friendly unit information is integrated with intelligence on enemy movement, to provide a clear picture of battlefield events. [Ref. 30:p. 13]

The individual command and control elements' friendly disposition data can be passed over the ATCCS tactical communication networks and consolidated at other command and control elements, thereby ensuring completeness of information and providing for large area coverage. [Ref. 10]

IV. CONCEPT ASSESSMENT

A. INTRODUCTION

The purpose of this chapter is to develop a methodology for assessing whether or not the VLF/IFF concept outlined in Chapter Three merits further consideration as a viable solution to the operational deficiency defined in Chapters One and Two. Once this methodology has been developed, it will be applied to the VLF/IFF concept to determine the proposed system's feasibility and assess its capability to satisfy the stated operational and organizational requirements outlined in Chapter Two. Finally, the concept will be evaluated against the current political, cost and scheduling constraints imposed on the military acquisition process.

The scope of this thesis precludes any comprehensive evaluation of a VLF/IFF system. The VLF/IFF concept is just that, a concept. A considerable amount of work has been done to develop the concept. However, several key tasks remain to be accomplished under the Army's Materiel Acquisition Process before a complete assessment can be undertaken. This chapter will attempt to provide an initial, rough assessment of the proposed system based on work already done and available material that can be extrapolated to apply to this proposal.

The results of this study should provide decision makers a preliminary assessment of the merit of developing this concept as a potential solution to the C2 requirement for near real time display of friendly force battlefield disposition.

B. ASSUMPTIONS

Any concept assessment must be conducted within the limitations of very real, always changing, usually loosely defined constraints. For this reason it is necessary to conduct the assessment at a specific point in time. This is done to minimize the impact of small fluctuations in the key variables while still providing meaningful measures to support program decisions. Any drastic fluctuations in the constraints will force the need for reassessment under the new set of constraints.

There were several assumptions necessary for this appraisal. They span the spectrum of political, fiscal, technical and operational considerations. They are general in context. However, they establish boundaries within which to conduct the assessment and against which to weigh the relative value of each of the assessment criteria.

1. **Valid Requirement**

The first and foremost assumption is that the requirement documented in Chapter One and stated in the Draft Operational and Organizational Plan at Appendix A will be approved as a valid system requirement.

2. **AirLand Battle Future**

The second assumption is that the evolution of the Army's AirLand Battle doctrine will progress as envisioned in the ALB-F concept. The 15 year time line established in the ALB concept defines the period over which these assumptions will be assumed valid.

3. **Threat Assessment**

The third assumption is that the projected threat assessment will remain valid. That is, the size of the threat will remain large, the quality of threat will continue to improve and the threat employment doctrine will not change significantly.

4. **Fiscal Restraint**

The fourth assumption is that the trend of reduced defense spending and manpower cutbacks will continue as the federal government attempts to reduce the budget deficit and restore a sense of fiscal responsibility.

5. **Technology**

The fifth and final assumption is that there will be no technological breakthroughs that dramatically change the way combat is conducted or command, control and communications is exercised. Although the frontiers of technology will continue to be pushed forward, industry's ability to introduce near term, usable, cost effective applications for combat will not improve significantly.

C. ASSESSMENT FRAMEWORK

The methodology used in this assessment was derived from an established, proven framework. Under Department of the Army (DA) guidance, this framework coordinates the efforts of the user and development communities in their efforts to define needs, identify solutions and provide useful products for use by combat forces.

The context within which this assessment was conducted is defined by:

- AirLand Battle doctrine,
- Army of Excellence force structure,
- Army Force Modernization / Integration Plan,
- C2 Mission Area Analysis (MAA),
- Materiel Acquisition Program (MAP),

- Planning, Progamming and Budgeting System (PPBS).

These framework cornerstones provide overall guidance on how to integrate the efforts of the individual communities to ensure proper division of responsibilities, reduce duplication of effort, focus limited resources and provide proper program management.

ALB doctrine establishes how U.S. Army combat forces will fight. It provides the context in which all other decisions on equipment, force structure and training are made. [Ref. 4]

AOE describes how U.S. Army combat forces will be organized to fight. It assigns forces and equipment against missions. [Ref. 6]

The Force Modernization / Integration Plan describes how new combat systems will be transitioned into the force. It stresses a smooth transition without an interim loss of capability.

The C2 MAA identifies deficiencies in the C2 mission area in terms of doctrine, force structure, training and materiel. This process ensures adequate interrelation between these components, provides a feedback mechanism for modification of existing programs and definition of needed programs. [Ref. 10]

The Materiel Acquisition Program establishes a process for providing needed materiel solutions to MAA identified deficiencies. This program stresses integration between the combat developer, materiel developer and DA leadership. Recent emphasis has been placed on streamlining the acquisition process while continuing to ensure adequate acquisition control mechanisms. [Ref. 46]

The PPBS provides guidance to the Army on funding for acquisition category programs. This is implementing guidance that translates what the political leadership allocates and how the services will disperse those allocations. This system reflects the fiscal realities of defense authorization spending and drives the efforts of those within the materiel acquisition community. This process in turn has a direct impact on the operational commanders and soldiers in the field today.

D. ASSESSMENT METHODOLOGY

The methodology developed in this assessment borrows from several well established and time proven evaluation processes. Issues for evaluation were extracted from Ref. 47. Specifically, the issues for evaluation include:

- reliability,
- interoperability,

- speed,
- security,
- flexibility,
- survivability,
- simplicity,
- economy.

These issues were initially developed to assess the technical aspects of a C2 system. However, their applicability to operational considerations is readily apparent. These general issues were overlaid on the operational and organizational requirements developed in Chapter Two and several key considerations outlined in the following references:

- Field Manual 100-5, OPERATIONS [Ref. 4];
- CONCEPT STATEMENT FOR AIRLAND BATTLE FUTURE (DRAFT) [Ref. 16];
- Field Manual 101-55, CORPS AND DIVISION COMMAND AND CONTROL [Ref. 48];
- Field Manual 101-5, STAFF ORGANIZATION AND OPERATIONS [Ref. 49];
- Field Circular 100-1, THE ARMY OF EXCELLENCE [Ref. 6];
- AMC-Pamphlet No. 70-2, TRADOC Pamphlet No. 70-2, AMC-TRADOC MATERIEL ACQUISITION HANDBOOK [Ref. 46];
- ARMY COMMAND AND CONTROL MASTER PLAN (DRAFT), Concepts and Management Volume 1 [Ref. 10];
- REQUIRED OPERATIONAL CAPABILITY FOR THE FAMILY OF ARMY TACTICAL COMMAND AND CONTROL SYSTEMS (ATCCS) [Ref. 23];
- Solicitation No. DAAB07-87-R-B076, ARMY COMMAND AND CONTROL SYSTEMS COMMON HARDWARE AND SOFTWARE [Ref. 50].

This resulted in the assessment design shown in Table 12 on page 129. These operational considerations parallel the technical criteria and should be used in conjunction with those considerations in any follow on VLF/IFF system evaluation.

These issues and considerations will be discussed as they apply to the VLF/IFF system. Discussion will focus on the potential advantages and possible problems associated with using the VLF/IFF approach outlined in Chapter Three. The VLF/IFF system will then be assessed against the following real world imperatives:

Table 12. ASSESSMENT ISSUES AND IMPERATIVES

ISSUES	
Reliability:	**Interoperability:**
-Maintainability	-Standardization
-Supportability	-Connectivity/Integration
-Availability	-Synchronization
Speed:	**Security:**
-Accessibility	-Information Encryption
-Timeliness	-Operational Security
-Agility	-Confidence
-Initiative	-Exploitability
Flexibility:	**Survivability:**
-Deployability	-Hardness
-Mobility	-Robustness
-Reconfigurability	-ECM Susceptibility
-Adaptability	-ECCM
Simplicity:	**Economy:**
-Transparency	-Operational Capabilities
-User Friendly	-Manpower Considerations
-Information Utility	-Training Requirements
-Simplification of Operations	-Trade Offs

IMPERATIVES	
Politics:	**Economics:**
-Acceptability	-Advanced Development
-Affordability	-Full Scale Engineering & Development
-Accessibility	-Production
-Technological Realities	
Technical Considerations:	
-Demonstration of Capabilities	
-Full Scale Engineering and Development	
-Development Test/Operational Test II	
-Production	
-Initial Operational Capability	

- politics,
- economics,
- technical considerations.

E. PRELIMINARY ASSESSMENT

1. Issues and Considerations

Each of the issues will be defined as they apply for the purposes of this discussion. Each of the operational considerations will be discussed as they relate to the VLF/IFF system. It is acknowledged that a VLF/IFF system does not exist today and that these discussions describe a potential capability based on information available at this time. An initial assessment will be made of a VLF/IFF system's capability with respect to each of the issues and their associated considerations. An overall assessment of the system's potential will be made in the next section along with recommendations for future actions.

a. Reliability

(1) Definition. Reliability establishes the degree to which a system will be available for use when it is most needed. This determination is based on whether the system can be maintained and sustained.

(2) Maintainability. All three of the basic components of the VLF/IFF system are the result of successful evolutionary development processes. They are, in essence, mature, proven, military and commercial technologies. IFF/RBS has been in existence over forty years, VLF and computers over thirty years.

All three technologies support numerous civil and military users under extremely demanding conditions every day. IFF/RBS supports over 100,000 users, VLF over 10,000 and computers millions. The basic IFF, VLF and computer components of a VLF/IFF system are in the Army inventory and in service today. [Ref. 51]

The types of users, operating environments, operating utilities and degree of user dependency on these technologies demands dependable system performance. Thousands of hours have been logged on the system components. Operating specifications are extremely stringent. VLF is a basic element of the U.S. strategic Minimum Essential Emergency Communications Network (MEECN) [Ref. 52]. OMEGA provides continuous, reliable, global navigation. Computer/software systems support continuous ATC and air defense operations the world over. These systems have proven their maintainability over years of service.

(3) Supportability. A strong industrial base is already established to support and provide additional components for this system with little or no lead time. This was demonstrated by a recent U.S. Army Avionics Research and Development Activity (AVRADA)/Tracor Industry project that equipped the Army CH-47 fleet and the 101st Airborne (Air Assault) Division C2 helicopters with OMEGA receivers [Ref. 51]. IFF is a required component on all military aircraft in service and in production. C2 computers and software are currently being fielded under the ATCCS program. In essence, IFF, VLF and computer equipments of the type required in the VLF/IFF system are already in the Army inventory and have well established support bases.

The support bases of these technologies is healthy and continues to support rapidly expanding commercial markets. IFF/RBS equipment is being installed on more and more civil aircraft each year. OMEGA is being purchased by most major airlines and there are numerous commercial OMEGA ventures ongoing [Ref. 42]. Several are very similar to what is being proposed in the VLF/IFF concept [Ref. 53].

(4) Availability. VLF and OMEGA provide worldwide navigation support to numerous air and marine users. OMEGA is the only certified, continuous, global navigation system in operation today. The VLF signals are like the earth's magnetic field, available, free, to anyone with a receiver.

IFF/RBS and computers are used in support of ATC and air defense operations by aviation users in every country in the world today. These technologies have proven themselves under the most demanding of environmental conditions. VLF, IFF and computers are all combat proven systems, as evidenced by their employment in the Falkland Islands War. [Ref. 54:pp. 25 & 218]

VLF and IFF systems are truly international in nature. Their component specifications and system operations are agreed upon and secured by international agreements. It is through this arrangement that system operation and availability are ensured.

(5) Initial Assessment. The VLF/IFF system's reliability appears excellent based on past performance, current operational use and projected system development. Potential problem areas include component integration, software development and acquisition community acceptance of the notion that today's technologies can be integrated effectively to achieve an evolutionary capability to meet future requirements.

b. Interoperability

(1) Definition. Interoperability establishes the degree to which a system will be capable of fighting effectively with other U.S. Army systems and in conjunction with the systems of other services and allies.

(2) Standardization. VLF/IFF offers a unique opportunity for a truly joint and combined interoperable system by locking all elements, air and land, to a common grid. VLF/IFF is a distributed system that allows for the fluid entry and exit of maneuver and C2 elements. VLF/IFF supports rapid reconfiguration of the C2 structure associated with joint and combined operations. The technology is currently available and employed by all U.S. Services and most, if not all, our allies. The VLF signal is available for the price of an inexpensive receiver. IFF systems are employed in almost all military aircraft today.

International treaties guarantee equipment compatibility and system operation. Transition to the Mark XV transponder demonstrates an international commitment to maintain and promote system compatibility and interoperability [Ref. 55:pp. 1-9]. Integration of these two technologies could easily provide one system for all.

(3) Connectivity/Integration. System compatibility, interface of procedures and message format design could easily be provided through the VLF/IFF system's integrating of these existing, internationally used systems.

VLF/IFF would ensure system integration throughout a theater of operation. This includes both vertical and horizontal transfer of information in the system. The system is similar to the NATO Identification System in its objective of providing a common, integrated combat picture to all users [Ref. 33].

(4) Synchronization. VLF/IFF would enhance a commander's ability to conduct complex, combined arms operations by providing a common battlefield reference grid in both time and place. This capability would enhance the conduct of joint and combined operations by significantly simplifying the coordination and timing necessary to execute these types of operations.

(5) Initial Assessment. The VLF/IFF system's interoperability appears excellent based on standardization of system components and operating procedures. Connectivity throughout appears possible due to demonstrated component compatibility. Interface operation procedures and message format design would be accomplished within existing standards. The realization of a theater wide synchronizing grid would

significantly enhance the conduct of combined arms operations in a joint and combined environment. Existing, operational OMEGA, VLF-COMM, IFF transponders and C2 components and systems would significantly reduce the development effort required to place a VLF/IFF system into operation. Potential problems include system integration, software development and allied acceptance of the VLF/IFF proposal.

c. Speed

(1) Definition. Speed defines the ease with which information can be entered and moved through a system and the degree to which that information enhances time dependent operations to ensure freedom of action.

(2) Accessibility. VLF/IFF would provide immediate access to all users. Tailoring of automatic update is provided based on user community, mission and system status.

The number of users the system will support is limited only by the number of maneuver elements a given C2 element can support. This number can be fairly large and is therefore usually insignificant.

Access to the net is accomplished with a one way, line of sight radio link, i.e., the transponder, to any C2 element possessing the VLF/IFF processor/display component. The ATCCS communications architecture would ensure C2 element connectivity.

(3) Timeliness. VLF/IFF provides commanders and their staffs an automated, near real time display system. The system generates and updates information at speeds measured in microseconds. This capability means that information is available to support decisions when it is needed, not minutes or hours later. There is no significant system initialization or preparation period.

Electronic data can be passed, processed and displayed as it is generated or at some user selected update rate. This capability supports the varied requirements of numerous operational communities.

(4) Agility. Immediate access and timely presentation of accurate information would greatly enhance the decision making process, providing for rapid correct responses to battlefield developments. Integration of the VLF/IFF display of real time friendly force disposition with real time intelligence on the enemy's disposition would allow a commander and his forces to operate within the enemy's decision cycle.

(5) Initiative. This increased ability to react immediately to real time battlefield developments can be translated into a capability to seize the initiative in any

conflict. Wresting the initiative from an enemy and causing him to react to U.S. actions is one of the four ALB tenets. [Ref. 4]

(6) Initial Assessment. The VLF/IFF system's speed appears excellent based on the system's ability to translate immediate access, near real time, accurate, usable information and improved reaction time into a capability to seize the initiative in any conflict. Potential problem areas could include operational delays introduced by the ATCCS communication system. High enough precedence must be provided to guarantee the transmission of timely, usable information.

d. Security

(1) Definition. Security establishes the degree of confidence with which information can be exchanged without compromise.

(2) Information Encryption. VLF/IFF offers information encryption through use of the transponder. Transmissions from the maneuver element are passed in encrypted form to the C2 element and then, through use of the ATCCS communication system and its encryption techniques, across the C2 network. Introduction of the Mark XV transponder will provide enhanced security to an already secure system. Encryption of the VLF signal is not necessary for secure system operation.

Additional security is provided by the random countdown of the IFF burst transmissions. This randomness complicates the enemy's collection problem by making it extremely difficult to synchronize to the transmitted IFF signal.

(3) Operational Security. The VLF component of the system is a passive receiver. The IFF transponder is the only active emitter. IFF, as currently operated, has established communications security (COMSEC) procedures. VLF/IFF would not require any major changes to these procedures. In fact VLF/IFF could easily be incorporated into the existing system with little adverse impact.

Some operations, for reasons of emission security, require that the IFF transponder be turned off for some specified period of time. This type of decision would have to be weighed against the need for real time position and tactical intelligence. These types of trade off decisions are made every day based on the mission and commander's concept of the operation.

IFF and processor/display components will be as secure as the systems they are operated in conjunction with. As envisioned, processor/display components would be procured under the ATCCS Common Hardware/Software Program. [Ref. 23]

As stated in Chapter Three, the increase in IFF transmissions required to generate the display information would place an insignificant additional load on the IFF system. In effect the signal generating the display would be camouflaged by the standard IFF signal. The additional communication load spread across the ATCCS communication network would be insignificant providing little additional information of use to the enemy. The enemy would have great difficulty determining if the system was even in operation.

Additional security is built into the system with the VLF/IFF synchronization key required to synchronize the system components to VLF stations and each other. Generation and distribution of this key would be handled within existing COMSEC channels.

(4) *Confidence.* As stated before, all VLF/IFF components have proven effective in combat operations. VLF/IFF system operations would be difficult and extremely costly to spoof. Several TOAs are required to calculate LOPs and position. Unique identities are locked to these measurements. Ambiguous measurements are rejected by the system. The VLF/IFF system would provide high level confidence of accurate and valid information.

(5) *Exploitability.* Since the VLF/IFF signal is camouflaged by other IFF transmissions it will be difficult for an enemy to exploit. Random countdown will make it difficult for the enemy to collect. Encryption will make extraction of useful information difficult. The C2 element remains a passive receiver of the IFF signal making its exploitation difficult. And the standardization of components and mobility of the maneuver elements makes it hard for an enemy to exploit the IFF signal for targeting.

To generate the same picture of U.S. forces, the enemy would have to capture or build a compatible system and possess and be able to use the IFF encryption key and the VLF/IFF synchronization key.

(6) *Initial Assessment.* The VLF/IFF system's security appears excellent based on existing, National Security Agency (NSA) approved, combat proven capabilities and system characteristics. Enhancement of system capabilities would occur with the fielding of the Mark XV transponder. High information confidence, low probability of system exploitability and minimal impact on existing COMSEC operations makes VLF/IFF very attractive from a security perspective. Potential problem areas include VLF/IFF synchronization code development and NSA approval.

e. Flexibility

(1) Definition. Flexibility establishes the degree of freedom to conduct combat operations without being constrainted by the C2 system.

(2) Deployability. VLF signals are available continuously anywhere on the surface of the earth, thus supporting immediate worldwide deployability of a VLF/IFF system in support of U.S. combat forces.

VLF receiver, IFF transponder and processor/display integration into the combat vehicle and C2 element will ensure rapid deployment of the system with the commanders and soldiers who depend on them to fight. This means VLF/IFF will be a self-contained system, providing immediate capability upon arrival.

(3) Mobility. VLF/IFF would be as mobile as the combat or C2 element with which it would operate. This includes man, ground vehicle and air platform configurations. Embedded system components and a common battlefield grid would enhance control and coordination of rapidly moving forces in a non linear environment. This system would allow a commander to wage combat without being tied to a battlefield positioning community. VLF/IFF may have a profound influence on the way in which the Army looks at all position/navigation (POS/NAV) requirements. In other words, VLF/IFF could provide a baseline POS/NAV capability for all communities. More stringent capabilities could be provided by a small set of specialized systems. This differs dramatically from the way today's POS/NAV architecture attempts to justify extremely accurate POS/NAV systems for all users based on numerous, conflicting and sometimes inconsistent functional and weapon system requirements. [Ref. 56]

(4) Reconfigurability. VLF/IFF could function independently in a stand alone mode or as part of an integrated command and control network. This modular capability allows for tailoring of the C2 system in support of low, medium and high intensity conflicts and unconventional operations, i.e., it can be a physical add on to any ATCCS. This allows commanders to develop C2 support slices based on force structure and composition.

(5) Adaptability. VLF/IFF system characteristics would greatly enhance the adaptability of a commander and his forces on the modern battlefield. The system is capable of supporting three dimensional operations at depth. VLF/IFF provides automatic altitude on aircraft and, due to the technique used to calculate position, remains accurate at all depths of the battlefield.

(6) Initial Assessment. The VLF/IFF system's flexibility appears excellent based on its ability to support rapid, worldwide deployment of combat forces, provide tailored support of forces in conflicts of varying intensity on the three dimensional AirLand battlefield. Potential problems include system integration and software development.

f. Survivability

(1) Definition. Survivability establishes the degree to which the system can effect command and control without being destroyed or neutralized.

(2) Hardness. Both VLF and IFF components are in use today with the 101st Airborne (Air Assault) Division providing support for real world mission requirements. Their ability to operate in harsh environments under stressful conditions has already been proven, both by the U.S. and the British.

ATCCS common hardware/software in some cases will be full military specification (MILSPEC) and in others will be NDI [Ref. 50]. VLF/IFF components would need to be only as hardened as the maneuver and C2 element equipments they support, and in most cases, VLF/IFF components are already hardened beyond those requirements.

(3) Robustness. VLF/IFF is basically a system of integrated components each capable of independent operations. There are no critical elements on the battlefield. The destruction or neutralization of one or any number of maneuver or C2 elements elements will have little impact on the overall system's ability to continue operations.

The rate at which the VLF/IFF system degrades would be relatively gradual given the fully distributed nature of the system, which places all players on a common, relative, positional grid and allows any of the elements to be equipped to generate an integrated AirLand display of friendly force disposition. Thus, graceful degradation of services and capabilities is an intrinsic feature of the VLF/IFF system.

(4) Electronic Countermeasure Susceptibility. The VLF signal cannot be effectively jammed, even at great labor and expense. It is therefore the least likely component of the system to be attacked. [Ref. 57]

The processor/display components are passive with respect to VLF/IFF, however they contribute to the thermal and electronic signatures of actively emitting C2 elements which are high priority targets for enemy attack or suppression.

The VLF/IFF components at these facilities will be susceptible to the extent that these C2 elements can be neutralized or destroyed.

The IFF signal is already camouflaged in an IFF haze provided by normal system operation. If the enemy chooses to jam the IFF system, he must do so from close range to overcome the transponder's signal power at the relatively short operational ranges and close conflict configurations specified in the VLF/IFF concept. There are rather severe costs levied on the enemy if he should choose to employ this strategy. These will not be discussed in this paper. Suffice it to say that, it is unlikely that this type of effort would last long enough to significantly preclude the use of the VLF/IFF system. Targeting the IFF signal for physical attack is complicated by the extremely short duration of the burst transmission and the randomness of the emission.

(5) *Electronic Counter-countermeasures.* VLF transmitters are dispersed geographically around the world away from likely battlefields. Although the signal is available for use, the transmitter is not available for attack on the localized battlefield. Even if the transmitters are close to the battle area, they are unlikely to be attacked due to their extensive use by all nations and the international treaties that guarantee their operation. This was the case with the Argentine station during the Falklands Island War. Both Argentine and British forces used the signal. These VLF stations are terrestial and, unlike satellite systems, guarantee the option of defending them should it become necessary.

Automatic, random, burst transmissions providing position, unit identification and tactical information would significantly reduce the amount of time spent trying to convey this information by voice. This feature would significantly reduce the enemy's ability to target U.S. combat elements.

The system components would be small and light weight, enhancing the mobility of the maneuver elements and C2 elements in which they were employed.

Projected enhancements to the IFF system with the fielding of the Mark XV transponder are expected to improve VLF/IFF system survivability even further.

(6) *Initial Assessment.* The VLF/IFF system's survivability appears excellent based on past performance of system components, the potential for graceful degradation of capability, the relative immunity to ECM and the degree to which VLF/IFF system components enhance the survivability of the maneuver elements and

C2 elements they support. Potential problem areas include susceptibility of the Mark XII transponder to jamming.

g. Simplicity

(1) Definition. Simplicity defines the degree to which the system simplifies a given function or operation.

(2) Transparency. VLF/IFF, integrated with ATCCS, would produce a fully automated reporting and display system. It would remove the human from the process with the exception of real time tactical information reporting. This would include reporting, data base update and communication system access. In effect, the process would go on around the commander and his forces without taking up their time, freeing them to concentrate on the business of combat. The system would be available to support the C2 process, as required, in a truly transparent manner.

(3) User Friendly. The VLF signal used by the VLF/IFF system is available at no cost to the operational user. No expenditure of effort is required to receive the synchronizing signal or ensure its continuous availability. The IFF component is set once or twice a day similar to changing radio frequencies. All equipment is standardized for ease of use and training.

The personnel who operate the system are combat vehicle operators and C2 element personnel. Little additional training would be required to operate the equipment. The receiver/processor component would, in essence, provide data to the ATCCS common hardware/software to drive graphic display utilities.

(4) Information Utility. The presentation of accurate, reliable, real time identification, position and status information in graphic form would definitely prove the notion that a picture is worth a thousand words. The technique by which VLF/IFF data is generated allows for presentation of friendly force disposition in whatever format the user community desires.

(5) Simplification of Operations. VLF/IFF would transition the function of unit position and status reporting from the manual, slow, resource intensive, inaccurate, unreliable, FM voice process occuring today to the automatic, near real time, accurate, and reliable process required by ALB commanders and their staffs.

VLF/IFF would allow a commander and his staff to focus their energies on more productive endeavors in support of mission accomplishment. This system would allow more time for reaction, planning and monitoring.

Transition to electronic medium would provide additional flexibility in the presentation, storage and manipulation of friendly disposition data. Those functions currently accomplished through the use of paper map sheets, acetate overlays and grease pencils could gradually be transitioned to automated display devices.

(6) Initial Assessment. The VLF/IFF system's simplicity appears excellent based on the automating of a currently resource intensive system to transparently provide a highly usable C2 product that would significantly simplify operations and allow the focusing of labor on more productive, mission oriented tasks. Potential problem areas include software development and institutional bias.

h. Economy

(1) Definition. Economy establishes the realizability or achievability of a system within given constraints.

(2) Operational Capabilities. VLF/IFF would streamline the reporting process through use of sophisticated electronic components and automation. The result being transparent generation of near real time, accurate and reliable battlefield information.

Timely, usable information enhances the decision making process. Shorter reaction times, more time for planning and monitoring execution makes for a more agile force capable of seizing and retaining the initiative in any conflict.

VLF/IFF system modularity would provide a commander additional flexibility in force design. In effect, any element of the combined arms team could lead or actively participate in the synchronizing of forces at minimal cost because of the distributed nature of the system.

VLF/IFF can be deployed rapidly on the same aircraft as the C2 systems and combat forces it supports and be operational immediately after arrival anywhere in the world.

(3) Manpower Considerations. A VLF/IFF system would require no additional personnel to operate or maintain. Operation of the system would be accomplished by the maneuver element crews and the C2 element operations personnel.

Maintenance functions could be accomplished by existing personnel and organizations within the current maintenance structure. This eliminates a need for a specialized skill or additional support organizations.

Training requirements would be minimal and could be inserted into existing service school curricula, thereby eliminating the need for system peculiar instructors.

(4) Training Requirements. VLF/IFF system instruction could be contractor developed and provided to service schools for incorporation into existing blocks of instruction on maneuver element and C2 system operations and maintenance. This approach would minimize the impact on current schooling operations and eliminate any requirement for development of a specialized curriculum.

Current operation and maintenance curriculums would be sufficient to support VLF/IFF system training requirements. Processor/display operation, the most demanding of the training requirements could be incorporated into ATCCS operator training or provided as on site instruction.

(5) Trade Offs. A key ingredient of economy is the ability to realize an intended system or product within the anticipated capabilities of the military industrial complex. Several recent program failures highlight this point, e.g., Sgt. York, Aquila and LHX.

VLF/IFF is unique in that the billions of dollars invested to mature the two technologies practically guarantees that there are no fundamental flaws which would prevent realization of the system. Thus, the military industrial community could integrate two fully operational systems through straight forward engineering to achieve a new and improved operational capability without risking realizability or achievability.

Acquisition of a VLF/IFF system would cost relatively little and free up valuable resources for investment elsewhere. Dollars saved by purchase of VLF/IFF could be invested in other combat system programs. Manpower savings could be redistributed to other critical functions. Improved operational capability would be realized immediately through a streamlined acquisition process vice waiting for longer research and development efforts. The VLF/IFF system represents an adequate, available, alternative for a dramatically new operational capability in contrast to an all encompassing, 'better' system sometime in the future.

(6) Initial Assessment. The VLF/IFF system's economy appears excellent based on enhanced operational capabilities, reduced manpower requirements, limited training impact and realization of a much needed, long overdue C2 capability now. Potential problems include institutional bias and strong, competitive, industry lobbying.

2. Real World Imperatives

a. Politics

(1) Acceptability. AirLand Battle doctrine is an accepted way of conducting combat operations among U.S. forces. As stated earlier, VLF/IFF is truly an ALB system. Acceptance within the U.S. community of a VLF/IFF system should be realizable.

Allied acceptance of the VLF and IFF system technologies should provide an indication of the acceptability of a VLF/IFF system. Over 140 countries have signed treaties guaranteeing the operation of these two system components [Ref. 30:p. 3]. These systems are operated by host nations. International forums have guaranteed VLF and IFF system evolution and enhancement well into the twenty first century. NATO Defense Ministers are committed to buying the Mark XV transponder as part of the NATO Identification System. It would seem that a VLF/IFF system might be easier to sell to our allies than has AirLand Battle doctrine.

There is also continuing growth in the commercial applications of these technologies that could prove beneficial to the military. These developments make VLF/IFF even more attractive and provide vitality to the technology base.

(2) Affordability. A big consideration for both the U.S. and our less wealthy allies is whether or not, in these times of renewed economic responsibility and reduced defense budgets, we can afford to pursue expensive, unproven technologies that promise capabilities well beyond present boundaries. Our allies for years have balked at our dollar rich approach to system development, opting instead for inexpensive, workable solutions. [Ref. 15]

The basic VLF/IFF components are in production and in use by all concerned. They are relatively inexpensive and have proven capable and reliable over years of service. The major investments in research, development, testing and evaluation (RDTE) and engineering costs have already been paid. Yearly maintenance costs are minimal. System integration and software development cost would be relatively small. Certainly the proposed VLF/IFF system would be affordable to all.

(3) Accessibility. The major components of VLF/IFF are available today and accessible to U.S. and allied civil and military users. Their international, non military operation makes them attractive from a political and budgetary standpoint.

(4) Technological Realities. VLF/IFF does not depend on other high technology systems for its operation, deployment, servicing or sustainment.

Frequencies have been reserved worldwide for the operation of these systems. This is provided for in international agreement.

The VLF/IFF component technologies are state of the art and a VLF/IFF system is obtainable through minor software development and system integration efforts. VLF/IFF is not a technology pipe dream. It is an obtainable capability.

b. Economics

Preliminary cost figures and program milestones have been developed by the Army technical community. These calculations do not reflect exactly the VLF/IFF system configuration outlined in this thesis. However, they do represent accurately the relative cost of the types of components discussed and should make it clear that VLF/IFF system costs would be less than a fraction of that being paid for most new systems.

(1) Advanced Development. The Army technical community stands ready to initiate the advanced development phase of a VLF/IFF program. The cost for brassboard fabrication and installation of two C2 elements, of different configurations, and ten maneuver elements has been estimated at 5 million dollars. A proof of concept/demonstration with troops could be conducted within a year from project initiation. The cost could be reduced to as little as 2.5 million dollars with a reduction of brassboard equipment and appropriate scaling of the size of the tactical force supported in the demonstration. Work on the full scale engineering and development (FSED) contract could begin late in the troop demonstration phase. [Ref. 58]

(2) Full Scale Engineering and Development. The Program Manager for the Army's Operations Tactical Data Systems (PM OPTDS) has been briefed on the VLF/IFF system and stands ready to begin system integration efforts. The total cost for FSED and Development Test/Operational Test II (DT/OT II), both internal and external, has been estimated at 15 million dollars. [Ref. 58]

(3) Production. Production costs have been estimated at 250 million dollars. This rough estimate provides for 10,000 maneuver elements at 10 thousand dollars apiece and 100 C2 elements, with and without displays, at 25 thousand dollars apiece. The 250 million dollar figure represents a more than doubling of the per unit costs to allow for logistic support and system integration costs. [Ref. 58]

c. Technical Considerations

VLF/IFF offers near term capability based on a streamlined acquisition process. This system capitalizes on previous RDTE and FSED efforts. Initial opera-

tional capability (IOC) could be realized in as few as 4 years after award of contract for demonstration hardware, depending on program prioritization and availability of funding. A proposed milestone schedule is depicted at Figure 50. [Ref. 58]

(1) Demonstration of Capability. This would be a proof of principle designed primarily to validate the technical aspects of the system and provide insight into organizational and operational considerations.

Ideally this demonstration would be conducted in conjunction with a tactical exercise with a VLF/IFF brassboard system used by and in support of operational commanders and their forces. This would allow for fine tuning of the Operational and Organizational Plan.

The Army Development and Employment Agency (ADEA), located at Fort Lewis Washington, offers an ideal facility for integrating the user, combat and materiel developers in support of such a demonstration. ADEA has been designated as one of the Army's C3I testbeds for just such demonstrations.

(2) Full Scale Engineering and Development. This phase of development would focus primarily on militarizing the hardware and software, configuring the equipment for integration with other C2 systems and fielding of the system.

This phase of the schedule would be the culmination of a competitive process that capitalizes on past VLF, IFF and computer/software expertise and development efforts.

(3) Development Test/Operational Test II. This portion of the schedule involves the validation of technical, operational and organizational capabilities. The results of this phase would feed the acquisition process and be used to determine whether or not to buy the system. Major issues to be resolved concerning VLF/IFF would likely include:

- operational effectiveness,
- system connectivity,
- software validation.

(4) Production. VLF/IFF would not require a long lead time to begin production. Many components are already in production and expansion of production lines should be a relatively simple process.

(5) Initial Operational Capability. VLF/IFF would be fielded in accordance with current C2 system fielding policy and would be closely tied to ATCCS fielding and evaluation.

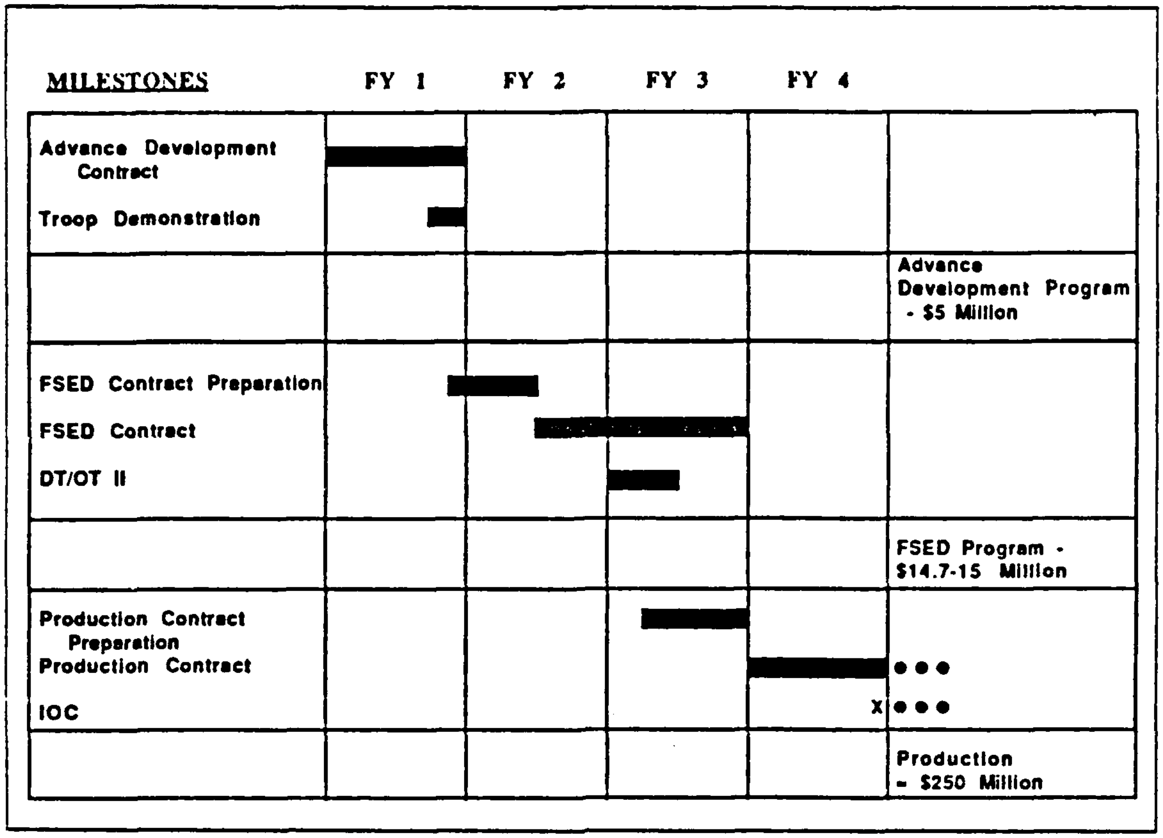

Figure 50. VLF/IFF Program Milestones

F. CONCLUSIONS

1. Technical Feasibility

The VLF/IFF system appears technically feasible. Given the availability and demonstrated performance of the three major system components, VLF/IFF is a very attractive technical solution to a very complex problem. Simple in its approach, VLF/IFF would provide an extremely robust and capable system. The system capitalizes on years of successful development efforts and technical achievements. VLF/IFF brings all the component strengths with it while minimizing potential problem areas. [Ref. 59:pp. 8-9]

2. Operational Potential

VLF/IFF's potential to provide significant enhancement to C2 functions in support of ALB doctrine appears extraordinary. Increased flexibility, survivability, reliability and agility are all likely results of VLF/IFF system employment. Coupled with

manpower savings and schedule considerations, VLF/IFF provides solutions to tomorrow's requirements today. [Ref. 59:pp. 8-9]

Additionally, coupling of VLF and packet radio technologies along the same line as VLF/IFF could produce an extremely robust communication and position reporting system with much greater operational capability than currently proposed data distribution systems.

3. Risk Assessment

In terms of the political, technical, operational, budgetary and schedule considerations discussed in Chapters Three and Four, VLF/IFF appears to be a low risk approach with high, near term payoff potential. [Ref. 59:pp. 8-9]

G. RECOMMENDATIONS

1. Operational and Organizational Plan

U.S. Army Training and Doctrine Command (TRADOC) staff the Draft Operational and Organizational Plan at Appendix A.

TRADOC provide approved Operational and Organizational Plan to AMC to initiate the materiel acquisition process.

2. Engineering Effort

U.S. Army Materiel Command (AMC) initiate a system engineering effort to further develop the technical specifications required to support a technical assessment of the VLF/IFF system.

AMC initiate the concept formulation process to address the requirement stated in the Operational and Organizational Plan.

3. Proof of Principle

TRADOC/AMC initiate discussions with ADEA and the 9th Infantry Division (Motorized) for the purposes of conducting a proof of principle demonstration using the C3I Testbed and 9th Infantry Division forces during a major field training exercise. Should ADEA and the 9th Infantry Division be unavailable, another candidate test unit would be the 101st Airborne (Air Assault) Division because of their current use of and experience with IFF and OMEGA equipment.

4. Packet Radio Experimentation

AMC explore application of VLF technology in Packet Radio experimentation process to evaluate its potential for application in an integrated communication/battlefield position reporting configuration.

APPENDIX A. OPERATIONAL & ORGANIZATIONAL PLAN (DRAFT)

1. TITLE:

   a. Near Real Time Information System (NRTIS)

   b. CARDS Reference Number:_______

2. NEED

   a. The U.S. Army requires a command and control (C2) system which permits commanders and staffs at all echelons of command to rapidly acquire, store, retrieve, disseminate, and display near real time information. Presently command and control is exercised at the various operating facilities (OPFACS) within each echelon of command using manual systems and procedures for collecting, storing, processing, displaying, and disseminating information. These systems are slow, manpower intensive, and often provide untimely and inaccurate information. The limited information management and display capabilities provided by today's C2 systems inhibits a staff's ability to provide the commander the critical information required for making timely decisions associated with the employment and sustainment of combat power on the AirLand battlefield.

   b. Airland Battle doctrine requires that the commander conduct and plan for three different battles (rear, close, and deep) on a three dimensional battlefield where operations will be conducted over greater areas, at greater speeds, and with greater lethality than in the past. To survive, forces will be more dispersed, but to win, they must be capable of massing quickly. These two factors have caused the volume of information required by a commander and staff to increase. The commander must, in near real time, have the ability to: see his force's disposition, know their current situation and status, and sense the enemy's intentions. The current manual C2 system cannot provide the commander and staff with this near real time information nor can it handle the increased information load required to support operations on the AirLand battlefield. The characteristics of the AirLand battlefield dictate the need for providing a commander and staff with an automated command and control system which can harness technology and use it as a force multiplier to synchronize the commander's combat power in time, space, and activity to defeat the enemy's physical and moral determination to fight.

   c. The NRTIS is capable of continuously providing the commander and staff with a unit's position, location, mission, combat posture, and operational readiness status. This system, through its interface with the Army Tactical Command and Control System (ATCCS) will significantly improve the generation and dissemination of battlefield information. Together, these systems (NRTIS and ATCCS) will provide the capability of rapidly collecting, correlating, filtering, processing, extracting, formatting, and displaying timely and accurate force disposition information for the force commander.

   d. The NRTIS concept contributes to solving six deficiencies identified in the TRADOC Battlefield Development Plan (BDP), 1986(S). The BDP provides a prioritized composite of mission area deficiencies as determined by each school

and center's Mission Area Analysis (MAA). These six deficiencies are items number: CC01, CC02, CC03, CC04, CC05, and CC09. The fielding of NRTIS will provide a total or partial solution to the BDP operational deficiencies noted.

3. THREAT

a. Threat to be countered.

1) Threat forces of the Warsaw Pact represent the most serious opposition likely to be faced by the U.S. Army in the forseeable future. These forces have long enjoyed the advantages of numerical superiority over the forces of NATO and in other theaters as well. The margin of this numerical superiority is increasing and is expected to continue into the next decade. The Threat's weapon systems and combat support systems continue to improve and these improvements constitute a significant enhancement to the threat's numerical superiority and a challenge the U.S. Army's qualitative and technological advantage. The Threat has made significant improvements in the areas of mobility (battlefield and strategic) and command, control, and communications. These improvements, when combined with their numerical advantage and other improvements, provides them the capability to conduct many simultaneous attacks and to rapidly shift or redirect forces to exploit success in any area.

2) A less serious form of conflict but one that the U.S. Army has a greater probability of becoming involved in deals with third world nations, counter insurgency operations or peace keeping missions. These operations are commonly referred to as low intensity conflicts and might require the rapid deployment of a force to a remote theater of operations (a non European scenario). This conflict would be characterized by highly lethal, intermittent combat actions. Clear and distinct lines of combat or fronts would not exist and U.S. forces might be widely dispersed to control more terrain and to be better prepared to immediately respond to contingencies. This greater dispersion of forces, lack of clear battle lines, and an enemy who is more familiar with the terrain present a serious threat to the U.S. force and a challenge to any command and control system which must support that force.

b. System Vulnerabilities

1) The NRTIS equipment and the vehicles, shelters, and command centers in which it will be operated, are vulnerable to attack by surface-to-surface missiles, tactical aircraft, dual capable artillery, multiple rocket launchers, airborne/airmobile forces, and unconventional warfare or special operations teams.

2) Some of the component elements of the NRTIS concept may be vulnerable to enemy electronic warfare systems which will attempt to intercept, deceive, and/or jam their transmissions. Electromagnetic pulses (EMP) from high altitude nuclear detonations do present a threat to the concept's components. EMP can burn out unprotected solid state circuits and can scramble memory logic in computer systems, thus inducing system failure. The communication systems which the NRTIS concept interfaces with at command centers are vulnerable to radio frequency weapons and if destroyed, they would negate the concept's ability to disseminate information beyond the command and control center.

3) The employment of persistent and nonpersistent chemical, biological, and toxic agents by threat forces remains a constant hazard. Post attack residual contamination and decontamination activities may require operators to assume higher levels of protective posture which might result in a slight reduction in system performance.

4. OPERATIONAL CHARACTERISTICS

a. To enhance the concept's overall survivability, the system has been conceived to consist of independent (stand alone) nodes. There is no critical node in the architecture. Therefore the loss of any one node has an insignificant effect on the entire system. The system will be capable of supporting worldwide operations in high, mid, and low intensity environments.

b. The NRTIS concept will:

1) Automatically provide near real time identification, location, and situational information (mission, combat posture, and operational readiness status) to a C2 node for command and control.

2) Improve the management of battlefield information for command and control functions by automatically collecting, correlating, filtering, processing, storing, and displaying identification, location, and situational information on all unit's operating in proximity of a selected command post.

3) Provide the commanders and staffs the ability to plan future operations, analyze alternative courses of action and assess the ramifications of a tactical decision.

4) Utilize ATCCS common hardware and software to obtain:

a) database functions (storage, retrieval, input/output of information) to support a commander and staff;

b) the capability to perform information input/output functions and to manipulate the system's capabilities;

c) a nonvolatile memory that will not purge itself if there is a sudden power loss;

d) the capability of loading new software and purging classified information in the field;

e) a full color, large screen display capable of depicting all of the information found in the system's database;

f) an interface with a large printer plotter to produce large paper and acetate overlays of various map scales from data stored in the database or displayed on the large screen display;

g) a capability to store, display, and manipulate decision graphics and standard military symbology as specified in the current edition of FM 101-5-1, OPERATIONAL TERMS and SYMBOLS;

h) a capability to handle information with a classification ranging from UNCLASSIFIED to SECRET;

i) an interface with the ATCCS communications networks;

j) a capability to link different databases at different locations to provide for a direct exchange of information without operator interface.

5) Interoperate with other automated systems in the joint and combined environments in compliance with the U.S. Message Text Format (MTF) Program and implement ATCCS MTF and battlefield functional area (BFA) unique requirements.

6) Exchange standard data elements in standard formats with other control systems found in other battlefield functional areas (BFAs) and in the joint and combined arenas.

7) Be air, water, and ground transportable.

8) Provide full military specification (MILSPEC) components capable of transmitting and receiving digital message traffic while mounted/moving in a manpack configuration or on armored and wheeled vehicles or aircraft commonly found in an Army of Excellence Division.

9) Provide nondevelopmental items (NDI) for use in semi-static or stationary C2 centers. NDI components will be ruggedized to permit transporting as cargo in wheeled and armored vehicles. If possible, the components should be mounted in the vehicles to allow for immediate initialization and operation once the vehicles have completed the move. The components should be capable of operating from a remote location approximately 100 meters from the vehicles/power source.

10) Provide MILSPEC devices capable of operation, transportation, and storage in climate design types hot, basic, and cold as defined in AR 70-38 and the requirements of MIL-STD 810 (dust/desert). NDI equipment will operate in sheltered facilities in temperatures ranging from 0 to 100 degrees Fahrenheit and in humidities ranging from 10% to 95% (noncondensing without environmental conditioning).

11) Provide MILSPEC and NDI equipment capable of operating in a NBC contaminated environment. MILSPEC items will be considered to be mission essential and should therefore be EMP hardened.

12) Provide MILSPEC and NDI equipment which will not be affected by NBC decontamination operations.

13) Be capable of being operated by soldiers dressed in full NBC environmental protective clothing and equipment (mission oriented protective posture level four, MOPP 4).

14) Provide for continuity of operations in accordance with AC2MP.

15) Not create a unique electromagnetic signature.

16) Facilitate standard equipment camouflage

5. OPERATIONAL PLAN

a. The Near Real Information Time System (NRTIS) is a command and control system which, in conjunction with Army Tactical Command and Control Sys-

tems (ATCCS), will provide, store, and display near real time information on friendly combat, combat support (CS), and combat service support (CSS) forces for commanders and staffs at various echelons of command (section to corps) under the Army of Excellence organization. This system, in conjunction with other ATCCS systems, will serve as a primary tool for gathering, correlating, filtering, processing, extracting, and displaying information on friendly forces. It will provide automated assistance in the development and coordination of plans and in monitoring the execution of current operations. This system will enable the staff to respond to a commander's critical information requirements in near real time. The NRTIS system, through ATCCS elements, will fuse information on friendly forces with other pieces of information to generate a near real time representation of the AirLand battlefield. This representation will enable a commander or staff to better visualize the true disposition of friendly forces against the perceived threat and to better synchronize the actions of friendly forces to seize the initiative and defeat the threat.

b. The system is a hybrid system which employs both MILSPEC and ruggedized commercial NDI equipment to fulfill the information collection, processing, storing, displaying, and disseminating requirements of tactical organizations. The system will consist of two sets of equipment:

1) the maneuver element set, for use by select combat, CS, and CSS elements on whom information is desired;

2) a command and control (C2) node set, for use by select command posts which must monitor the operations of maneuver elements. This set will also possess all of the capabilities incorporated into the maneuver element.

c. The maneuver element is the information generator in the system. It will employ the unique characteristics of VLF/IFF technologies to automatically and periodically transmit its identification, location, mission, combat posture, and operational status to any C2 node. The functions of a maneuver element's set will normally be transparent to its operators and will not inhibit its/his ability to perform its/his primary combat/tactical mission. At initialization of operations, the operator will load the maneuver element's identification, mission, combat posture, and operational readiness status into the system. The system will automatically function using this information until such time as the operator (through an interface device) or another system on the maneuver element changes one of the information elements. The system will automatically generate and provide the data required by the C2 node to determine the maneuver element's location.

d. The C2 node is the collector, displayer and disseminator of information. The functions performed by this set will also be transparent to its operators and it will:

1) automatically provide information about itself to other C2 nodes, as if it were a maneuver element;

2) automatically collect transmissions emitted by any maneuver element operating in proximity to it;

3) automatically store processed maneuver element transmissions into information which determines the maneuver element's identification, location, mission, combat posture, and operational readiness status;

4) employ ATCCS common hardware and software to:

   a) automatically update a database system and an operational display device with the processed information;

   b) provide operator interface devices for manipulation of the system's hardware and software;

   c) support staff planning and operating functions.

5) interface with the communication networks of the ATCCS to disseminate/receive information to/from higher and lower echelons of command.

6) pass information received over communication networks to the database and display modules.

7) A C2 node will consist of the following modules: an antenna module, a transceiver module, an operator interface module, a database module, a large screen operations display module, and a communications interface module. The number of operator interface modules and large screen display modules available at a command post (or as part of a command post's C2 node) may differ based on echelon of command and staff requirements.

6. ORGANIZATIONAL PLAN

a. General

b. The NRTIS will be employed within all BFAs in both heavy and light corps; armored, infantry, light infantry, mechanized, motorized, airmobile, and airborne divisions; separate heavy, light, and theater defense brigades; and armored cavalry regiments. The system will augment the manual C2 system, replacing some functions such as: the collection of periodic situation reports, updating of friendly information on operations maps, maintenance of status charts, and the preparation of overlays and periodic reports. The system will be operated by personnel assigned to organizational elements performing C2 functions and operating maneuver elements. The distribution of hardware is based on the following force structure and units:

1) Active Force Structure. (Includes associated RC round-out units.)

• Corps:	I, III, V, VII, XVIII
• Heavy Divisions:	1ID(M), 3ID(M), 4ID(M), 5ID(M), 8ID(M), 24ID(M), 1CAV, 1AD, 2AD, 3AD
• Motorized Divisions:	9ID
• Infantry Divisions:	2ID
• Airborne Divisions:	82ABN
• Air Assault Divisions:	101ABN(AA)
• Light Divisions:	6ID, 7ID, 10ID,

	25ID
• Heavy Separate Brigades:	197IN.(M), 177AR, 194AR
• Armored Cavalry Regiments:	2ACR, 3ACR, 11ACR
• Theater Defense Brigades:	193IN, Berlin Brigade

2) Reserve/National Guard Force Structure.

• Heavy Divisions:	35IN(M), 40ID(M), 49AD, 50AD
• Infantry Divisions:	26ID, 28ID, 38ID, 42ID, 47ID
• Light Divisions:	29ID
• Separate Infantry Brigades:	33IN, 39IN, 41IN, 45IN, 29IN,
• Armored Cavarly Regiments:	107ACR, 278ACR
• Separate Heavy Brigades:	30IN, 32IN, 81IN, 157IN, 218IN, 30AR, 31AR, 116AR, 163AR
• Theater Defense Brigades:	53IN, 73IN, 92IN, 187IN

c. Employment

1) The full MILSPEC devices will be fielded and provide hardened survivable C2 capability to all command posts that must perform mobile and critical command and control functions at any echelon of command. This will include but not be limited to: corps, division, regimental, brigade, and battalion main and forward main command posts.

2) The NDI devices will be fielded to fulfill automation requirements at locations not requiring full MILSPEC devices. The selection of locations to receive NDI equipment will be based on enemy threat, environment, and mission criticality.

3) TRADOC schools and centers will identify those combat, combat support, and combat service support elements which will be designated as maneuver elements using mission, dispersion, rate of movement, availability, criticality, and mode of employment as decision criteria. These criteria are defined in Annex A, to be published (TBP).

4) TRADOC schools and centers will identify those headquarters elements within combat, combat support, combat service support elements which will be designated as C2 nodes using mission, dispersion, rate of movement, availability, criticality, and mode of employment as decision criteria. These criteria are defined in Annex B (TBP).

5) TRADOC schools and centers will identify the number of operator interface modules and large screen display modules to be authorized per C2 node based on a headquarter's staff functions and needs (see ATCCS Basis of Issue Plan)

7. SYSTEM CONSTRAINTS

a. Mobility/Transportability

1) Transportable by air, water, and ground means.

2) System will not overburden the transportation assets available to the organization in which it is deployed. Ideally the system will become an integrated component of any vehicle/command center that is authorized to employ it.

3) Air transportability includes being capable of roll on, roll off transport on a variety of cargo aircraft (USAF C-130, C-141, C-5A, and C-17) and being transportable by helicopters.

4) The design of the equipment should not impede the speed with which a unit or section can emplace or displace in tactical situations.

5) Regardless of the command posts location, the system will be capable of providing the commander or staff the required critical information.

b. Power

1) The system will be powered by military tactical generators, 28 Volt DC vehicular and aircraft power supplies, and by commercial power (110-115/220-230 Volt AC, 50/60/400 Hz) dependent upon configuration.

2) The system must maintain memory for at least five minutes during power loss or fluctuations to allow archiving of data.

c. Manprint

1) Manpower and Personnel

a) System will be operated by TO&E personnel currently performing manual command and control functions therefore no additional personnel will be required to operate the system.

b) The system will, for the most part, consist of ATCCS common hardware or other components which are currently and/or will be in the Army inventory. Those MOS's identified to repair this common equipment will support this system's maintenance programs. Personnel requirements to support the maintenance of non-standard equipment is yet to be determined but its impact is perceived to be minimal.

2) New Equipment Training (NET)

a) Initial training of operators will be conducted in units by New Equipment Training Teams (NETT) IAW AR 350-35. Army Materiel Command (AMC) will provide the NETTs.

b) Displaced Equipment Training (DET): This system will not displace any system currently in use therefore there is no need to provide for DET. If

this system is fielded to USAR units then additional NETT will be required as specified above.

c) Institutional Training: Training on the use and employment of NRTIS concept will be integrated into the programs of instruction at selected TRADOC schools and centers.

d) Non-Institutional Training: Operational (field) sustainment training will be provided by embedding tutorials in the system's software. Tutorials will be designed with critical task training problem situations and exercise which approximate those expected to be encountered in actual tactical operations.

e) Training Devices, Simulators, and Simulation: None required.

f) Test Training Support Packages (TTSP): TBD.

g) System Safety/Health Hazard Assessment: Operation of this system will present no unusual safety or health hazard.

3) Logistics

a) The system will be issued with a complete logistics package, to include repair parts, technical manuals, Class II requirements, and special tools required to support operator/organizational and intermediate direct support maintenance programs.

b) Maintenance Concept

i. Operator/Organizational: Operators will perform maintenance IAW Preventive Maintenance Checks and Services (PMCS) as directed by the appropriate operator manual. Using built-in test equipment (BITE) and diagnostic software, operators will perform organizational maintenance troubleshooting. BITE will perform fault detection and isolation programs will identify the malfunctioning component and direct the appropriate corrective action (i.e.: "replace circut card A23"). The operator will evacuate malfunctioning components through their organic maintenance section which will evacuate the components to the intermediate direct support level. The operator should require a minimal number of tools to extract and replace system components.

ii. Intermediate Direct Support Maintenance: TBD.

iii. Intermediate General Support Maintenance: TBD.

iv. Depot Level Maintenance: TBD.

d. Environmental

1) MILSPEC equipment must be capable of surviving NBC contamination and the effects of high altitude electromagnetic pulse (HAEMP). NDI equipment must be capable of operating in similarly contaminated environment.

2) MILSPEC must meet the environmental requirements of AR 70-38 (climatic design types hot, basic, and cold). NDI equipment must operate in temperatures ranging from 0 to 100 degrees fahrenheit.

e. Communications: This system will be capable of passing information that has been processed via the ATCCS link over the full range of tactical and commercial communication systems including local area network (LAN) technology. The system must provide for efficient transmission of data to support distributed information requirements.

8. STANDARDIZATION AND INTEROPERABILITY

This system will be able to interoperate with all other systems in the ATCCS and with automated C2 systems of other joint and combined military forces.

9. FUNDING IMPLICATIONS

a. RDTE Costs: To be determined (TBD).

b. Procurement Costs: TBD.

c. Unit Cost: TBD.

d. Life Cycle Costs: TBD.

10. ANNEXES

a. Annex A - Operational Mode Summary/Mission Profile (OMS/MP): TBP.

b. Annex B - Rationale: TBP.

c. Annex C - Coordination: TBP.

APPENDIX B. ABBREVIATIONS, ACRONYMS, AND TERMS

AC	Alternating Current
AC2MP	Army Command and Control Master Plan
AD	Air Defense
ADA	Air Defense Artillery
ADEA	Army Development and Employment Agency
ALB	AirLand Battle
ALB-F	AirLand Battle Future
AMC	Army Materiel Command
AOE	Army of Excellence
AR	Army Regulation
ARINC	Airlines Radio Incorporated
ASAS	All Source Analysis Section
ATC	Air Traffic Control
ATCCS	Army Tactical Command and Control System
ATCRBS	Air Traffic Control Radar Beacon System
AVRADA	Avionics Research and Development Activity
BFA(s)	Battlefield Functional Area(s)
BITE	Built In Test Equipment
C2	Command and Control
CARS	Combat Arms Regimental System
CCS2	Command, Control, and Subordinate System
CEOI	Communications and Electronic Operating Instructions
CEP	Circular Error Probability
CIM	Communications Interface Module
cm	centimeter(s)
COL	Colonel
COMINT	Communications Intelligence
CP	Command Post
DA	Department of the Army
DC	Direct Current
DM	Database Module

DOD	Department of Defense
DT/OT	Development Test/Operational Test
ECCM	Electronic Counter-Countermeasures
ECM	Electronic Countermeasures
EW	Electronic Warfare
FAAR	Forward Area Alerting Radar
FLOT	Front Line of Own Troops
FM	Field Manual
FM	Frequency Modulation
FSED	Full Scale Engineering and Development
FSK	Frequency-Shift Keying
GDOP	Geometric Dilution of Position
GEN	General
GFE	Government Furnished Equipment
HUMINT	Human Intelligence
ICAO	International Civil Aviation Organization
IFF	Identification Friend or Foe
IOC	Initial Operational Capability
IVIS	Inter-Vehicle Information Systems
JMSA	Japanese Maritime Safety Agency
kHz	kilohertz
km	kilometer(s)
KPH	Kilometers Per Hour
kW	kilowatt(s)
LHX	Light Helicopter, Experimental
LIC	Low Intensity Conflict
LOIM	Limited Operator Interface Module
LOP	Line of Position
LSOD	Large Screen Operational Display
MAA	Mission Area Analysis
MEECN	Minimum Essential Emergency Communications Network
MG	Major General
MHz	Megahertz
MILSPEC(s)	Military Specification(s)

MOPP	Mission Oriented Protective Posture
MSE	Mobile Subscriber Equipment
MTBF	Mean Time Between Failures
MTF	Message Text Format
mW	milliwatt(s)
μs	microsecond(s)
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological, Chemical
NDI	Nondevelopmental Item
NIS	Nato Identification System
NRTIS	Near Real Time Information System
ns	nanosecond(s)
NSA	National Security Agency
NTA	Norwegian Telecommunication Administration
OIM	Operator Interface Module
OPTDS	Operations Tactical Data Systems
OR	Operational Readiness
PLL	Prescribed Load List
PM	Program Manager
POS/NAV	Position/Navigation
PPBS	Planning Programming and Budgeting System
PRC	Peoples Republic of China
RBS	Radar Beacon System
RDTE	Research, Development, Testing and Evaluation
rms	root-mean-square
RTCA	Radio Technical Commission for Aeronautics
sec	second(s)
SINCGARS	Single Channel Ground and Airborne Radio System
SITREP	Situation Report
SOP(s)	Standard Operating Procedure(s)
SSR	Secondary Surveillance Radar
STANAG	Standard NATO Agreement
TADDS	Target Alerting Data Display
TOA	Time of Arrival

TRADOC	Training and Doctrine Command
UHF	Ultra High Frequency
UPS	Universal Polar Stereographic
U.S.	United States
USA	United States of America
USAF	United States Air Force
U.S.S.R.	Union of Soviet Socialist Republics
UTM	Universal Transverse Mercator
VLF	Very Low Frequency
VLF COMM	Very Low Frequency Communication

LIST OF REFERENCES

1. Joint Military Terminology Group, *Joint Chiefs of Staff (JCS) Publication 1, Department of Defense Dictionary of Military and Associated Terms*, U.S. Government Printing Office, 1 January 1986.

2. Orr, G. E., *Combat Operations, C3I: Fundamentals and Interaction*, Air University Press, 1983.

3. Taylor, James G., *Lecture Notes, OS-3636, C3 Architecture*, Naval Postgraduate School, Monterey, CA, September 1987.

4. U.S. Army Command and General Staff College (ATZL-SWD), *FM 100-5, OPERATIONS*, U.S. Army Adjutant General Publications Center, 25 May 1986.

5. Rogers, John B., COL, US Army, "Synchronizing the AirLand Battle", *Military Review*, v. 66, pp. 65-71, April 1986

6. U.S. Army Combined Arms Combat Developments Center (ATZL-CAF-F), *FC 100-1, The Army of Excellence*, U.S. Army Adjutant General Publication Center, 1 September 1984.

7. Gorman, P.F., GEN, U.S. Army, "What the High Technology Edge Means", *Defense Magazine*, p. 22-31, June 1983.

8. U.S. Army Armor School (ATSB-CS-B(CSS)), *FC 71-8, Army of Excellence - Close Combat Heavy Brigade and Divisional Armored Cavalry Squadron Organizations*, U.S. Army Armor School, October 1984.

9. *The Army Command and Control Master Plan (Draft)*, U.S. Army Combined Arms Combat Developments Activity, 1985.

10. *The Army Command and Control Master Plan, Concept and Management (Draft)*, v. 1, U.S. Army Combined Arms Combat Developments Activity, 1 September 1987.

11. U.S. Army Institute for Military Assistance (ATSU-TD-TL), *FM 100-20, Low Intensity Conflict*, U.S. Army Adjutant General Publication Center, 6 January 1981.

12. U.S. Army Command and General Staff College (ATSW-CD), *TC 101-5, Command and Coordination of Division Operations*, U.S. Army Adjutant General Publication Center, 1976.

13. U.S. Army Combined Arms Combat Developments Center (ATZL-CAT), FM 100-2-1, Soviet Army Operations and Tactics, U.S. Army Adjutant General Publication Center, 16 July 1984.

14. *Operational and Organizational Plan (Draft) for the Maneuver Control System (MCS)*, Headquarters, Department of the Army.

15. Lopez, R., "The AirLand Battle 2000 Controversy, Who Is Being Short-Sighted", *International Defense Review*, no. 11, pp. 1551-1556, November 1983.

16. *AirLand Battle Future Concept Paper*, U.S. Army Combined Arms Center, 16 June 1987.

17. Directorate of Combat Developments, U.S. Army Armor Center, *Operational and Organizational Plan (Draft) for the Inter-Vehicle Information System*, March 1987.

18. McLaughlin, J., *Gettysburg, The Long Encampment*, Appleton and Century, 1963.

19. Woodmansee, J. W., MG, U.S. Army, "Blitzkrieg and the AirLand Battle", *Military Review*, v. 64, pp. 22-39, April 1984.

20. *Required Operational Capabilities for the Position Location Reporting System (PLRS)/Joint Tactical Information Distribution System (JTIDS) Hybrid,* Headquarters, U.S. Army Training and Doctrine Command, 8 September 1986.

21. *Operational and Organizational Plan for the Family of Army Tactical Command and Control Systems (ATCCS),* U.S. Army Combined Arms Combat Developments Activity, 6 December 1986.

22. *Webster's Ninth Collegiate Dictionary,* G.&C. Merriam Co., p. 1174, 1973.

23. *Required Operational Capability for the Family of Army Tactical Command and Control Systems (ATCCS),* U.S. Army Combined Arms Combat Developments Activity, 9 December 1986.

24. U.S. Army Combined Arms Center (ATZL-SWA-DL), *FM 101-5-1, Operational Terms and Symbols,* U.S. Army Adjutant General Publication Center, 21 October 1985.

25. U.S. Army Combined Arms Center (ATZLCA-DL), *FM 71-3, Armored and Mechanized Brigade Operations,* U.S. Army Adjutant General Publication Center, 25 June 1980.

26. U.S. Army Air Defense Artillery School, (ATSA-DTT-D), *FM 44-1, United States Army Air Defense Artillery Employment,* U.S. Army Adjutant General Publications Center, 9 May 1983.

27. U.S. Army Air Defense Artillery School, (ATSA-TDT-S), *FM 44-3, Air Defense Artillery Employment Chaparral Vulcan/ Stinger,* U.S. Army Adjutant General Publication Center, 15 June 1984.

28. U.S. Army Air Defense Artillery School (ATSA-TD-LITW), *FM 44-6, Operations and Training Forward Area Alerting Radar (FAAR) and Target Alerting Data Display Set (TADDS),* U.S. Army Adjutant General Publication Center, 24 March 1980.

29. Chief of Air Defense Artillery, Headquarters, U.S. Army Air Defense Artillery School, UNCLASSIFIED, CPT Francis G. Mahon, Subject: Air Defense Artillery Highlights 4-87, 20 January 1988.

30. Litchford, G. B., Saganowich, J. T., "An Omega /Transponder Display System", paper presented at International OMEGA Association Annual Meeting, 11th, Quebec, Canada, August 1986.

31. Clough, D. L., Hekl, R. A., Litchford, G. B., Johler, J. R., and Cooke, A. R., *The AVIES Study: Collected Documents,* JPL D-2801, Jet Propulsion Laboratory, 15 October 1985.

32. Honold, P., *Secondary Radar, Fundamentals and Instrumentation,* Siemens Aktiengesellschaft, Heyden & Sons LTD., 1976.

33. Coombs, L. F. E., "Identification in NATO", *Jane's Defense Weekly*, v. 8, no. 3, 25 July 1987.

34. Skolnik, M I., *Radar Handbook*, McGraw-Hill Inc., 1970.

35. Stanley, W. D., *Electronic Communications Systems,* Reston Publishing Company, Inc., 1982.

36. U. S. Department of Transportation, *Omega Global Radionavigation, A Guide For Users,* United States Coast Guard, November 1983.

37. Maloney, E. S., *Dutton's Navigation and Plotting,* 14th ed., Naval Institute Press, 1985.

38. Doubt, R. J., "Validating the Omega Signal", *Avionics*, October 1985.

39. Endter, E. W., "Survey of Worldwide Omega Users", *Navigation Journal of the Institute of Navigation,* v. 33, no. 3, Fall 1986.

40. Beukers, J. M., "A Review and Applicaitons of VLF and LF Transmissions for Navigation and Tracking", *Navigation Journal of the Institute of Navigation,* v. 21, no. 2, Summer 1974.

41. King, L. D., "Omega/VLF Flight Tests Over the U. S.", *Avionics,* October 1985.

42. Buckwater, L., "Outlook on Omega", *Avionics,* October 1985.

43. Vego, M., "Soviet Submarine Communications", *Signal,* v. 42, no. 3, November 1987.

44. Browne, J., "Crystal Oscillators Set Frequency Standards", *Microwaves & RF,* February 1987.

45. Miller, I., Freund, J. E., *Probability and Statistics for Engineers,* 3d ed., Prentice-Hall, Inc., 1985.

46. *Materiel Aquistion Handbook,* Headquarters, United States Army Materiel Command, Headquarters, United States Army Training and Doctrine Command, 26 March 1987.

47. Hoffer, N. J., *Application and Expansion of the Modular Command and Control Evaluation Structure (MCE) As a Framework For Acquisition Management,* Master's Thesis, Naval Postgraduate School, Monterey, California, March 1987.

48. U.S. Army Command and General Staff College (ATZL-SWA-DL), *FC 101-55, Corps and Division Command and Control,* U.S. Army Command and General Staff College, 28 February 1985.

49. U.S. Army Combined Arms Center (ATZL-SWA-DL), *FM 101-5, Staff Organizations and Operations,* U.S. Army Adjutant General Publication Center, 25 May 1984.

50. *Solicitation No. DAAB07-87-R-B076, Army Command and Control Systems Common Hardware and Software*, Headquarters, U.S. Army Communications-Electronics Command, 16 March 1987.

51. Feder, E., Ohliger, R. *The U.S. Army Omega Navigation Program*, paper presented to the International Omega Association Annual Meeting, 12th, Honolulu, HI, 19-13 October 1987.

52. Martin, T.L., *Command, Control, and Communications Mission and Organization: A Primer*, Masters Thesis, Naval Postgraduate School, Monterey, California, March 1984.

53. Stratton, A., *Reducing the Errors and Extending the Coverage of Differential Omega*, paper presented at the International Omega Association Annual Meeting, 12th, Honolulu, HI, 19-23 October 1987.

54. Ethel, J., Price, A., *Air War South Atlantic*, MacMillan Publishing Company, 1983.

55. *Mark XV Identification Friend or Foe (IFF) System Multiservice Test and Evaluation Master Plan (TEMP)*, Combat Identification System Program Office, Air Force Systems Command, 6 December 1984.

56. *The Army Position Navigation Master Plan*, United States Army Combined Arms Combat Development Activity, May 1986.

57. TRACOR Aerospace, *Tactical Jamming of the Omega Navigation System* , Internal Document, May 1986.

58. U.S. Army Communications-Electronics Command, *Army Airspace Command and Control Project*, briefing presented to the U.S. Army Technology Integration Steering Committee, March 1986.

59. Lawson, C. L., Wise, M. R., Saganowich, J. T., "Army Airspace Command and Control (A2C2)", paper presented at the U.S. Army Aviation Electronics Symposium, Asbury Park, N.J., 5-7 May 1986.

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